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CONTENTS.

No. 1–2. JANUARY-FEBRUARY.

No. 3 MARCH.

No. 4. APRIL.

No. 5. MAY.

No. 6. SEPTEMBER.

No. 7. OCTOBER.

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THE EXPERIMENTAL BASIS FOR THE PRESENT STATUS OF CORN BREEDING.[1]

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With an increasing knowledge of heredity, different systems of corn improvement have been proposed from time to time. The possibilities of progress under these methods has been the subject of experimentation, and it is the object of this paper to consider the results of these experiments in order to fix the present status of corn breeding. For convenience, methods based on self fertilization will be considered under pure-line breeding, reserving other sections for methods utilizing open-fertilized stocks.

Qualitative improvement of corn without reference to the effect on yield is too well understood to warrant more than mention. Such characters as height of plant or ear, angle of ear, number of suckers or ears per plant, type of ear, and composition of grain have been altered almost at will. Mass selection, pedigree selection, and pure-line methods, alone or in connection with hybridization, have been used to secure such modifications. However, the main object of corn breeding is to increase production, and improvement, therefore, will be construed to refer to increase in yield.

MASS SELECTION.

Because of the large size of the seed units, the ears, a certain

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amount of mass selection has been practiced by corn growers since the earliest times, and the results of planting a mixture of shelled grain obtained without selection, as is the seed of the small grain crops, can not be imagined. It seems to be generally conceded, however, that this selection has been of the utmost importance in improving corn and adapting it to the varying conditions under which it is grown. There also is ample evidence that success in adapting varieties to new environments may still be achieved by the same method, either alone or preceded by hybridization.

The ideas of the earlier corn breeders differed widely as to what constituted the best type of ear. This is shown by such varieties as Reid, Leaming, Hickory King, Gourdseed, and the small-eared prolifics which illustrate differences in the ideals of the breeders who established them. Some growers even believed that it was undesirable to select for a specific type, and made it a point to include choice representatives of different types in each year's selection. With increasing competition at corn shows, standards for judging the exhibits became desirable, and at the exposition in Chicago in 1886 the judges formulated a set of such standards for their guidance. In 1891 Orange Judd prepared a score card for the Illinois State Fair at Peoria, and this was modified and adopted later by the Illinois Corn Growers' Association. Once conceived, the idea was quickly adopted in other States, and so was born the corn score card.

In all probability seed value was not the important point at issue in these earlier corn shows—that is, a farmer's ability to produce a fine corn crop by the use of good soil, good seed, and good cultivation was measured by the sample of the crop, not seed, that he showed. As early as 1895 Plumb (69, p. 56)[3] noted that such a score card "has no more value than a scale of points in judging butter, where the breed of cow and her profitable character are not considered." Nevertheless it was but natural to assume that seed selected on the same basis would produce increased yields. Accordingly, score-card selection was preached, printed, and sung. When such selection was practiced, however, the progress was not all that had been anticipated, and experiments were undertaken to determine what relation there really was between the physical characters of seed ears and yield.

A large number of comparisons between seed ears differing in some specific character have been reported, based on the results of ear-to-row tests (5, 11, 22, 52, 56, 57, 58, 66, 67, 68, 76) and selection (66, 89, 90). Slight differences were found between the yields of the

[3] Reference is by number to "Literature cited," p. 14–17.

Table 1.—*Summary of comparisons between seed ears differing in some specific character.*

Seed ear character.	Reference.	Number of comparisons reported and crop years covered.							
		Total.		In favor of ears possessing designated character to the degree stated.					
				Large.		Medium.		Small.	
		Comparisons.	Crop years.	Comparisons.	Crop years.	Comparisons.	Crop years.	Comparisons.	Crop years.
Weight	(5)	16	16	15	15	..	..	1	1
	(56)	4	4	3	3	..	..	1	1
	(56, 57)	9	9	9	9	..	..	0	0
	(58)	2	11	1	4	..	..	1	7
	(66)	6	21	5	18	..	..	0	0[a]
	(89)	2	2	2	2	..	..	0	0
	Total	39	63	35	50	..	..	3	9
Length	(5)	16	16	16	16	..	..	0	0
	(11)	9	33	4	14	3	10	2	9
	(56)	4	4	4	4	..	..	0	0
	(56, 57)	9	9	6	6	..	..	3	3
	(58)	2	11	2	11	..	.	0	0
	(66)	6	20	4	16	..	..	2	4
	(90)	10	40	7	28	..	..	3	12
	Total	56	133	43	95	3	10	10	28
Circumference	(11)	9	28	1	1	4	17	4	10
	(57)	5	5	5	5	..	.	0	0
	(58)	2	11	1	4	..	..	1	7
	(66)	6	20	3	6	..	..	3	14
	Total	22	64	10	16	4	17	8	31
Shelling percentage	(5)	16	16	6	6	..	..	10	10
	(11)	1	1+	0	0	0	0	1	1+
	(56, 57)	6	6	0	0	..	..	6	6
	(57)	5	5	1	1	..	..	4	4
	(66)	6	21	2	8	..	..	4	13
	(90)	6	6	2	2	..	..	4	4
	Total	40	55+	11	17	0	0	29	38+
Number of rows	(5)	16	16	7	7	..	..	9	9
	(11)	7	20	0	0	3	3+	4	4+
	(56)	4	4	0	0	2	2	2	2
	(56, 57)	9	9	5	5	..	..	4	4
	(67)	1	1	0	0	1	1	0	0
	(75)	9	9	5	5	4	4	0	0
	(90)	13	13	2	2	4	4	7	7
	Total	59	72	19	19	14	14+	26	26+
Indentation	(11)	8	31	0[b]	0	1	6	7[c]	25
	(67)	1	1	0[b]	0	1	1	0[c]	0
	(90)	7	7	3[b]	3	..	..	4[c]	4
	Total	16	39	3[b]	3	2	7	11[c]	29

[a] One tie. [b] Rough. [c] Smooth.

various types, but these were too small to be significant in any one experiment and the conclusion has been practically unanimous that slight physical differences are of no value in determining the relative productiveness of good seed ears. For certain characters that have been studied most extensively, however, detailed results (5, 11, 56, 57, 58, 66, 67, 89, 90) are now available covering a large number of comparisons. These have been summarized in Table I without regard to the size of the differences.

Inasmuch as these data are based on comparisons between ears all of which were suitable for seed, the preponderance of evidence in certain cases seems convincing in spite of the fact that the determining differences in yield are small. There is every indication that selection on the basis of production, weight of ear in this case, is of value. Likewise it is indicated that it is preferable to obtain production by adding to the length rather than to the circumference of the ears, and that smoother, fewer-rowed ears with a lower shelling percentage than the standard show type are inclined to be the better yielders.

These indications are in accord with the results Hughes obtained from a comparison of 500 unselected ears (34). He found that the best 50, as picked by the majority of the 25 men who judged them, yielded not over 5 bushels per acre more than the bulk of the ears. He also concluded that ears that are inclined to be smooth with larger, coarser kernels and with more space between the rows than generally have been selected probably are best. They also agree with the reported results of several direct comparisons between a long smooth type and the rougher standard show type (18, 20, 51, 60, 67, 71). Hutcheson and Wolfe (39) drew their conclusions from a study of the progeny, rather than of the seed ears. Even so, they found that the relation between yield and percentage of grain, number of rows, average length of kernels, and space between rows was small.

It is possible that this superiority of the smoother, fewer-rowed ears was due to their persistence in a population selected too closely in another direction, as there is good evidence that close type selection may decrease yields (6, 54, 81). The superiority also may be inherent, or may be due to better seed condition caused by better maturity and greater freedom from disease (31). Whatever the cause, it seems evident that they were slightly better yielders, and the further considerations of quality and disease resistance appear to warrant selection toward a longer, smoother, fewer-rowed type than heretofore has been recommended.

The greater efficiency of producing a pound of grain on two ears rather than one has been noted by East (12) and is indicated by the

greater potential productiveness of the prolific varieties (73, 83, 84, 85) and the influence of ear-bearing tillers on yield (21, 60). Selection for 2-eared stalks has not always resulted in larger yields (70, 71), however, so that the evidence favors total production per plant as a sounder basis for selection than either size or number of ears.

Vigor, as measured by vegetative development, is associated with productiveness (10, 17, 19, 60, 61) and may serve as a selection index at an early period in the plant's growth (19, 55). Selection for such characters as height of plant or ear, however, produces conflicting results as regards yield (35, 52, 70, 71, 74, 82, 90), depending on climatic conditions in the different localities or seasons. This is well illustrated by Montgomery's results (61) in which plants having a 14 percent larger relative leaf area produced more under conditions of abundant moisture, but less under a limited water supply, than did the less leafy plants. Therefore, altho various plant characters may be used as an index in adapting a variety to specific conditions, the results of Ewing (17) and Montgomery (60, 61) show that they are of little value in selecting for yield within an adapted variety.

Finally, there is some evidence in favor of selecting under conditions of severe competition (49, 60, 90). These increases seem too small to warrant planting at excessive rates as a method of improvement, but sufficient to warrant the recommendation to select under conditions of uniform stand and fertility (88).

The limits of progress under mass selection in the sense of cumulative improvement are not now, and probably never will be, known. Regardless of whether these limits have been reached with our so-called improved varieties or not, the evidence shows that mass selection on the basis of production and quality, at least from the standpoint of maintaining yields, is entirely warranted.

HYBRIDIZATION.

Hybridization has a dual rôle in plant breeding. With corn, its use in securing new combinations for future selection has been common in practice, whereas investigations have been confined largely to the value of its immediate utilization in the first generation.

Following the results of Beal (1, 2) in 1878 to 1881, experiments were conducted from time to time to determine the possibilities of utilizing first-generation varietal crosses to obtain larger yields. In the experiments reported prior to 1893 (1, 2, 40, 59, 63, 64, 75), 14 of the 15 crosses tested produced increased yields. The method did not become popular, however, and was neglected until, after a lapse of some 16 years, the utilization of first-generation crosses was

again suggested by Shull (77), East (14), and Collins (8). Since then many crosses have been compared with their parents. Data on 244 tests of crosses between standard varieties that have been reported in some detail (24, 26, 28, 30, 38, 46, 65, 90) have been summarized in Table 2. These may well be taken as representative of all, as a survey of other reported crosses (3, 4, 6, 8, 9, 14, 15, 20, 25, 26, 47) does not indicate that they would materially affect the results.

TABLE 2.—*Summary of 244 comparisons between first-generation crosses and the parent varieties of corn.*

Reference.	Number of crosses.								
	Total.	Less than poorer parent.	As compared with average of parents.		Better than the better parent.				
			Above.	Below.	Total.	By the percentage stated.			
						0–5.	6–15.	16–25.	26+.
(24).......	96	4	83	13	51	14	26	9	2
(26).......	36	1	29	7	19	8	8	3	0
(28).......	2	0	2	0	0	0	0	0	0
(30).......	33	2	28	5	22	3	9	6	4
(38).......	4	0	3	1	1	0	1	0	0
(46).......	50	2	44	6	33	18	13	2	0
(65).......	10	3	3	7	3	1	2	0	0
(90).......	13	2	9	4	7	6	1	0	0
Total......	244	14	201	43	136	50	60	20	6
Percentage.	100.0	5.7	82.4	17.6	55.7	20.5	24.6	8.2	2.5

In these 244 comparisons 82.4 percent of the crosses produced more and 17.6 percent produced less than the average of the parents. This is conclusive as to the tendency of hybrid vigor to increase yields. Moreover, 136 of these crosses, or 55.7 percent, produced more than either parent. In such more or less haphazard crossing, therefore, the chances seem about equal of obtaining a cross that is or is not better than the better parent. The chances of obtaining a really advantageous cross—that is, one which will produce significant increases over the best of the local varieties for a series of years—are much less than equal. The best evidence as to the tendency of crosses to produce similar results in successive seasons is that from the Minnesota station (30). Crosses compared for a period of from two to four years each indicate that really significant increases obtained in one season, in general, may be expected in other seasons. That this is not absolute, however, is shown by the same data, and by the results at the Connecticut station (46, Table X, p. 339). As

pointed out by Jones (46), this is no more than is to be expected from combinations of varieties, which themselves vary so widely in yield in different seasons.

There appears to be a marked tendency (24, 26, 30, 46) for the largest actual yields to result from crosses between two varieties, both of which are high yielding, but which nevertheless differ considerably in type. The influence of the yield of the parents on the yield of the crosses is shown in Table 3.

TABLE 3.—*Comparison of first-generation crosses and the parent varieties.* (Compiled from Minn. Agr. Expt. Sta. Bul. 183, Tables 2, 8, and 9, p. 10, 18, and 19.)

Pistillate parent.	Yield in terms of Minnesota No. 13.		Cross exceeds Rustler yield.	Cross exceeds the average of parents.	
	Pistillate parent.	Cross.		Length of ear.	Number of rows.
	Percent.	*Percent.*	*Percent.*	*Inches.*	
FLOUR:					
Blue Soft	96.7	132.5	20.4	0.8	−1.2
FLINTS:					
Smutnose	110.8	127.6	15.5	0.6	−0.4
King Phillip	100.0	119.9	7.8	0.6	−0.4
Longfellow (NK)	100.5	119.6	7.5	0.5	−0.3
Longfellow (Bwls)	104.9	114.1	2.0	0.7	−0.9
Mercer	91.8	97.3	−14.8	0.1	−0.7
DENTS:					
Northwestern	105.9	115.7	3.6	..	..
Chowen	99.0	114.9	2.8	..	..
Rustler	112.1	112.4	0.3	0.2	0.1
Minnesota 23	96.7	110.9	− 1.2	0.3	0.2
Silver King	100.9	106.7	− 5.4	0.0	0.1
Murdock	89.3	101.6	−10.5	0.0	0.2

Table 3 also illustrates the effect of extreme differences in type in the larger increases obtained from crosses between flours or flints and dents than from crosses of dent varieties. Similar flint-dent crosses have produced large increases at the Connecticut station (26, 46), and crosses between southern dents and flints also have produced good yields (3, 4). Of the 14 crosses tested in Maryland by the United States Department of Agriculture in 1910 (24), two of the three advantageous ones were between Cross 120 and Hickory King as pistillate parents and Boone County White as staminate parent. Hickory King is an 8-rowed dent with large kernels. Cross 120 is a selection from an earlier Hickory King-Boone County cross, and has a somewhat longer, larger ear than Hickory King, but fewer rows and larger kernels than Boone County. This is interesting in view of the fact that the larger yields obtained from the flint-dent crosses

in Minnesota (30) was definitely associated with increased length and decreased number of rows, as shown in Table 3.

In the results reported by Hayes and Olson (30), in which eight of the twelve crosses produced more than the best of the thirteen parent varieties, the average increase was only 2.3 percent above this best variety. Even reciprocal crosses may differ so widely that one is advantageous, whereas the other is not (72). It obviously is as unreasonable, therefore, to condemn the utilization of first-generation crosses because they do not average more than the best local variety (49) as it is to recommend their indiscriminate use. It is evident that first-generation crosses offer possibilities for obtaining material increases in yield, but the value of each cross must be determined experimentally.

There seems to have been no direct investigation of the possibility of maintaining or increasing the yields of desirable crosses in succeeding generations. Referring to the crosses between Hickory King and Boone County compared in Maryland in 1910, Hartley notes that Cross 120, "after six years of selection and adaptation, produces somewhat less than the first-generation cross of the same parents made in 1909" (24, p. 19). One example is hardly conclusive, however, and in view of the fact that many of our present varieties were originated by hybridization followed by selection, it would seem that such an investigation might produce results of much interest.

EAR-TO-ROW BREEDING.

The ear-to-row method of corn breeding was introduced by the Illinois Agricultural Experiment Station about 1896 (32), and was accepted almost immediately at many of the experiment stations and by seedsmen and farmers. There have been various modifications of the method since its introduction, the more important of which may well be mentioned briefly.

One class of modifications had as its object a reduction in experimental error. Hunt (37) planted each ear in duplicate rows in different parts of the plat. Williams (86) used systematically distributed rows planted with uniform seed as a check on soil variation. Hopkins and his associates (33) compared only those rows that were grown in the same quarter of the breeding plat. Kyle (53) compared the yields of the individual ears thru the yield of uniform seed grown in the same hills as a standard. Discussion of these methods is unnecessary. From studies of field-plat technique, it now is well recognized that without replication such ear tests are of little or no

value, and that their reliability increases with the frequency of the checks and the number of replications. Other modifications were a method suggested by Hopkins and his associates (33) for preventing inbreeding, and the remnant system and introduction of "new-blood" ears suggested by Williams (86, 87) to insure high-yielding parentage on the staminate as well as on the pistillate side and to avoid close breeding.

Both increased (23) and decreased (50) yields following ear-to-row selection have been shown by comparing yields over two successive periods of years. Such measurement is unreliable, however, because of climatic influences (50). The more common test of progress has been to compare the yields of progenies of high-yielding ears with the yields of field selected seed. Results of such comparisons may be summarized as follows:

Hartley (22) obtained an average increase of 18 bushels per acre as a result of one year's selection.

Noll (65) reports a decrease of 4.7 bushels, and increases of 0.2, 0.3, and 6.2 bushels per acre in different tests, or an average of 0.5 bushel increase. Noll's results with crosses between high-yielding ears were no more significant, eight producing less and seven producing more than the field seed, with an average decrease of 2.4 bushels per acre.

Montgomery (60) reports increases of 9.5 bushels per acre after four years' and 7 bushels per acre after five years' continuous selection. From a single selection based on a two years' test he obtained an increase of 9 bushels per acre. Montgomery (60, 62) concluded that a single, careful selection on the performance basis followed by mass selection apparently was as efficient as continuous ear-to-row breeding. Since then Kiesselbach (49) has reported on later generations of these two methods. The average of the eighth to twelfth generations of continuous pedigree selection produced no increase over the original stock, whereas the seed that was mass selected following the single ear-to-row test produced 1.2 bushels per acre more than the original strain during the same years.

Hume (36) obtained an average increase over seven years' continuous breeding of 2.4 bushels per acre. During the last three of these years a different method of comparison showed a decrease of 0.2 bushel per acre. Hume (36) also compared the Illinois method for preventing inbreeding (33) with a more simple method involving no detasseling and found no appreciable difference between the methods, as an average for seven years.

Olson, Bull, and Hayes (66) compared ear-type selection with selection for ear type and yield, and secured an average increase for eight years of 5.6 bushels per acre due to the selection for yield. Of the eight comparisons, three showed negligible decreases and five increases, the range being from minus 0.3 to plus 21.1 bushels.

Williams and Welton (90) report the production of 20 crosses between high-yielding ears which were tested for one to three years each. Eighteen of these were better and two slightly poorer than field seed. The averages of the 3 to 4 strains from each mating produced increases in every case, ranging from 3.6 to 7.6 bushels per acre, the average increase during the eight seasons covered being 5.0 bushels per acre.

There is abundant proof from these results that altho individual progenies of high-yielding parents vary from actual decreases to considerable increases, as an average they may be expected to produce more than field selected seed. An original gain apparently has been lost in subsequent generations of close breeding (49, 60, 62). Close breeding is no essential part of the ear-to-row method, however, and may be prevented.

Finally, tho there is no evidence of cumulative improvement, the results of the Ohio station (90) indicate that an increase of about 5 bushels per acre can be secured and maintained under favorable conditions when close breeding is prevented. This increase is from the immediate progeny of high-yielding ears, and how much of it will persist in succeeding generations is not clear. The results at the Nebraska station (49, 60, 62), however, show that such a difference becomes less in succeeding generations.

It seems quite probable that the yield of an entirely unselected or unadapted variety could be improved by a few years' intelligent ear-to-row selection. However, in view of the expense, the uncertainty with which larger yields have been obtained, and the small increases secured during a series of years in the most favorable cases, so far there appears to be little to recommend ear-to-row breeding as a practical method of corn improvement.

PURE-LINE BREEDING.

The utilization of crosses between pure lines was first suggested by Shull (77, 78). East (14) and East and Hayes (15) accepted such a method as theoretically correct, but of doubtful value because of practical considerations. More recently Jones (43) has suggested that crosses between pure-line crosses be used commercially, over-

coming two of the serious practical objections, namely, the high cost and poor quality of the seed. The fundamental fact that inbreeding in corn results in a loss of vigor, which is regained when the isolated strains are again combined, is proved beyond question (13, 14, 15, 27, 28, 29, 42, 45, 49, 62, 65, 77, 78, 79, 80). Moreover, increased yields have been obtained from some combinations in every experiment reported.

In 1908 Shull obtained yields of 74.4 and 78.6 bushels per acre from the reciprocal crosses between pure lines, in comparison with 75 bushels from the two non-inbred parent varieties (78). In 1909 reciprocals of the best hybrid combination produced 98.4 and 96.1 bushels per acre, as compared with 88.1 bushels from the best non-inbred strain (79), and in 1910 he obtained 68.07 bushels per acre as an average from 7 hybrids, as against 61.52 bushels from 10 non-inbred strains (80).

The results of East and Hayes (15, 28) are conclusive as to the return to vigor following the crossing of pure lines. Inasmuch as these crosses were grown between rows of the inbred parents, however, and the reported yields of the non-inbred varieties were obtained in different seasons and, in one case, in a different locality (42, pp. 28, 57), the data have little relation to the question of obtaining larger yields by the use of pure line crosses.

Kiesselbach (49) gives the average yield of 11 pure-line crosses during three years as 53.4 bushels per acre, in comparison with 52.6 bushels from the original variety. It is unlikely that all of the crosses yielded equally, and some, therefore, probably exceeded this 0.8 bushel increase.

Of the 20 pure-line crosses tested by Noll (65) at the Pennsylvania station, 13 produced more and 7 produced less than the original variety. The 3 best crosses in 1914 produced increases of 11.5, 6.4, and 5.9 bushels per acre, and the 4 advantageous crosses in 1915 averaged 7.7 bushels per acre more than the non-inbred parent. These differences have been computed on a basis of 7,000 stalks per acre and 70 pounds of ears per bushel, the data having been reported as yields in pounds, from 50 stalks in 1914 and from 40 stalks in 1915.

Jones (42, Tables 11, 12, pp. 48, 49) reports the yields of 25 crosses between inbred strains of Leaming. These have been brought together in Table 4 in such a way as to show the parentage of the crosses. The yield of the original Leaming variety is given (42, Table 11, p. 48) as 80.8 bushels per acre. Of the 25 crosses, 14 produced more and 11 produced less than 80.8 bushels per acre. Of the

11 poor crosses, 6 had the 1-9-1-2 strain as pistillate parent, and 3 were crosses between the 1-7-1-1 and 1-7-1-2 strains which are more closely related. Moreover, all of the 8 crosses having the 1-6-1-3 strain as pistillate parent were high yielding. This is interesting as an indication of the consistent value of individual lines. Jones (42) notes that the seeds of strain 1-9 are the most poorly developed, whereas those of strain 1-6 are best, and suggests this as a possible cause of the differences.

TABLE 4.—*Yields in bushels per acre of crosses among pure-line strains of corn.*

(Compiled from 42, Tables 11, 12, p. 48, 49.)

Staminate parent strain.	Pistillate parent strain.				Average.
	1-9-1-2	1-7-1-2	1-7-1-1	1-6-1-3	
1-9-1-2.....	....	82.1	100.5	82.4	
	....	....	....	91.0	
				86.7[a]	89.8
1-7-1-2.....	59.6	....	70.9	101.0	
	66.3	....	....	106.2	
	63.0[a]			103.6[a]	79.2
1-7-1-1.....	58.0	55.9	....	112.9	
	52.5	58.4	....	99.1	
				94.8	
	55.3[a]	57.2[a]		88.1	
				98.7[a]	70.4
1-6-1-3.....	63.9	106.7	99.9	....	
	71.5	84.9	84.4	....	
			59.4	....	
	67.7[a]	95.8[a]	40.5	....	
			71.1[a]		78.2
Average......	62.0	78.4	80.8	96.3	

[a] Average.

Hayes and Garber (29) give the production of three crosses between two strains of Minnesota 13, previously inbred for three generations, as 51.4, 51.3, and 54.2 bushels per acre, in comparison with 48.9 bushels from the non-inbred stock.

In all of these experiments the crosses were at a disadvantage due to poor seed condition caused by the weakness of the pistillate parent. This factor is eliminated in double crosses, and Jones reports yields of 112 and 117 bushels of shelled grain per acre from double-crossed

seed, as against 92 bushels from the best variety so far found in Connecticut (43, 44).

The results prove that increased yields can be obtained from crosses or double crosses between pure lines. Can the same combinations be relied upon to produce yields in successive seasons that sufficiently exceed those which may be obtained by simpler methods to compensate for the expense of producing and crossing the pure lines? The evidence indicates that they can, but the number of experiments in which such crosses have been tested under strictly comparable conditions seems too small so far to warrant definite conclusions as to the practical possibilities of this method as a means of obtaining larger yields of corn.

CONCLUSION.

There is another and better reason for using pure-line methods in experimental corn breeding. Thruout these experiments certain basic principles are evident. First, selection produces larger yields as it secures better adaptation to the specific environment, or picks out the more favorable hybrid combinations. Selection inevitably results in decreased vigor and consequent yield, however, whenever it tends to the isolation of pure lines. Second, hybridization, whether between varieties or strains, results in increased vigor. Finally, there is a tendency for the largest actual yields to be produced when the best products of selection are used in hybrid combination. These principles long have been recognized. They attain a new significance, however, with the more recent Mendelian interpretation of hybrid vigor as the result of the combined effect of linked dominant growth factors (41, 48). The theoretical aspects of this interpretation in its relation to corn breeding have been discussed in detail by East and Jones (16) and by Jones (45), and such a consideration is beyond the scope of the present paper. Briefly, it permits the use of the same methods in pure-line breeding that have been partially successful with open-fertilized stocks, namely, selection, hybridization, and further selection, but all based on pure lines and controlled pollination.

There seems to be little reason for hesitating between methods founded on ever-changing hybrids of unknown constitution and methods in which definite pure lines, that can be reproduced at will, form the basis for improvement; or between the older methods that retained unfavorable recessive characters, but attempted to suppress them by blind hybridization, and pure-line methods that cause the

expression of these characters so that they may be recognized and eliminated. It is to be hoped that experiments will be undertaken to ascertain the possibilities in pure-line methods of corn breeding on a scale commensurate with the importance of the subject, and under methods that are in keeping with present knowledge, not only of genetic principles, but also of field-plat technique.

The possibility of progress under pure-line methods is largely theoretical so far, and it is entirely possible that unrecognized principles may interfere with the fulfillment of present expectations, as they have with those in the past. Nevertheless, the entire evidence from all corn-breeding investigations for the present points to pure-line methods as the only sound basis for real improvement of corn.

LITERATURE CITED.

1. BEAL, W. J. *In* Rpt. Mich. Bd. Agr. 1880, p. 287–288.
2. ——. *In* Rpt. Mich. Bd. Agr. 1881–82, p. 136.
3. BELLING, JOHN. Corn crosses. *In* Fla. Agr. Expt. Sta. Rpt. 1912, p. 127–129. 1912.
4. ——. Hybrid corn. Fla. Agr. Expt. Sta. Press Bul. 196. 1912.
5. BIGGAR, H. HOWARD. The relation of certain ear characters to yield in corn. *In* Jour. Amer. Soc. Agron., 5: 230–234. 1919.
6. BRUNSON, A. M. The first generation cross between two strains of corn bred for high and low ears. *In* Trans. Ill. Acad. Sci., 9: 87–91. 1916.
7. COLLINS, G. N. The importance of broad breeding in corn. U. S. Dept. Agr., Bur. Plant Indus. Bul. 141, p. 33–44. 1909.
8. ——. The value of first generation hybrids in corn. U. S. Dept. Agr., Bur. Plant Indus. Bul. 191. 1910.
9. ——. Increased yields of corn from hybrid seed. In U. S. Dept. Agr. Yearbook for 1910, p. 319–328. 1911.
10. CRAIG, C. E. Some correlations between physical characters of the maize plant, and between the physical characters and nitrogen content. Reference in Ewing (17, p. 75).
11. CUNNINGHAM, C. C. The relation of ear characters of corn to yield. *In* Jour. Amer. Soc Agron., 8: 188–196. 1916.
12. EAST, E. M. The relation of certain biological principles to plant breeding. Conn. Agr. Expt. Sta. Bul. 158, p. 87. 1907.
13. ——. Inbreeding in corn. *In* Conn. Agr. Expt. Sta. Rpt. for 1907, p. 419–428. 1908.
14. ——. The distinction between development and heredity in inbreeding. *In* Amer. Nat., 43: 173–181. 1909.
15. ——, and HAYES, H. K. Heterozygosis in evolution and in plant breeding. U. S. Dept. Agr., Bur. Plant Indus. Bul. 243. 1912.
16. ——, and JONES, D. F. Inbreeding and Outbreeding: Their Genetical and Sociological Significance. 277 p. Philadelphia: Lippincott Co. 1919.
17. EWING, E. C. Correlation of characters in corn. Cornell Univ. Agr. Expt. Sta. Bul. 287. 1910.

18. FUNK, EUGENE. Ten years of corn breeding. *In* Amer. Breeders' Mag., 3: 295–302. 1912.
19. GRANTHAM, A. E. The relation of the vigor of the corn plant to yield. *In* Jour. Amer. Soc. Agron., 9: 341–343. 1917.
20. ——. Report of field crops work at the Delaware Station, 1918. Del. Agr. Exp. Sta. Bul. 122, p. 10–20. 1918.
21. HARTLEY, C. P. Value of corn pollen f om suckers *vs.* from main stalks *In* Proc. Amer. Breeders' Asso., 2: 141–144. 1906.
22. ——. Progress in methods of producing higher yielding strains of corn. *In* U. S. Dept. Agr. Yearbook for 1909, p. 309–320. 1910.
23. ——. Circular letter of U. S. Dept. Agr., Office of Corn Investigations, 1914. Reference in Kiesselbach (50, p. 75).
24. ——, BROWN, E. B., KYLE, C. H., and ZOOK, L. L. Crossbreeding corn. U. S. Dept. Agr., Bur. Plant Indus. Bul. 218. 1912.
25. HARTWELL, B. L., and DAMON, S. C. Miscellaneous experiments with corn. R. I. Agr. Expt. Sta. Bul. 173, p. 9–10. 1918.
26. HAYES, H. K. Corn improvement in Connecticut. *In* Conn. Agr. Expt. Sta. Rpt. for 1913, p. 353–384. 1914.
27. ——. Normal self-fertilization in corn. *In* Jour. Amer. Soc. Agron., 10: 123–126. 1918.
28. ——, and EAST, E. M. Improvement in corn. Conn. Agr. Expt. Sta. Bul. 168. 1911.
29. ——, and GARBER, R. J. Synthetic production of high protein corn in relation to breeding. *In* Jour. Amer. Soc. Agron., 11: 309–318. 1919.
30. ——, and OLSON, P. J. First generation crosses between standard Minnesota corn varieties. Minn. Agr. Expt. Sta. Bul. 183. 1919.
31. HOLBERT, J. R., and HOFFER, G. N. Control of the root, stalk, and ear rot diseases of corn. U. S. Dept. Agr. Farmers' Bul. 1176, p. 13. 1920.
32. HOPKINS, C. G. Improvement in the chemical composition of the corn kernel. Ill. Agr. Expt. Sta. Bul. 55. 1899.
33. ——, SMITH, L. H., and EAST, E. M. Directions for the breeding of corn, including methods for the prevention of in-breeding. Ill. Agr. Expt. Sta. Bul. 100. 1905. Second edition, 1907.
34. HUGHES, H. D. An interesting seed corn experiment. *In* Iowa Agriculturist, 17: 424–425, 428. 1917.
35. HUME, A. N. Breeding experiments with cereals. *In* S. Dak. Agr. Expt. Sta. Ann. Rpt. for 1913, p. 24–31. 1913.
36. ——. Yields from two systems of corn breeding. S. Dak. Agr. Expt. Sta. Bul. 184. 1919.
37. HUNT, THOMAS F. The Cereals in America, p. 195. New York: Orange Judd Co. 1905.
38. HUTCHESON, T. B., and WOLFE, T. K. The effect of hybridization on maturity and yield in corn. Va. Agr. Expt. Sta. Tech. Bul. 18. 1917.
39. ——, ——. Relation between yield and ear characters in corn. *In* Jour. Amer. Soc. Agron., 10: 250–255. 1918.
40. INGERSOLL, C. L. Purdue Univ. 7th Ann. Rpt., p. 87. 1882.
41. JONES, D. F. Dominance of linked factor as a means of accounting for heterosis. *In* Genetics, 2: 466–479. 1917.
42. ——. The effects of inbreeding and crossbreeding on development. Conn. Agr. Expt. Sta. Bul. 207. 1918.

43. ——. Inbreeding in corn improvement. *In* Breeders' Gaz., 75: 1111–1113. 1919.
44. ——. The basis for corn betterment. *In* Wallace's Farm., 44: 2514–2515. 1919.
45. ——. Selection in self-fertilized lines as the basis for corn improvement. *In* Jour. Amer. Soc. Agron., 12: 77–100. 1920.
46. ——, HAYES, H. K., SLATE, W. L., and SOUTHWICK, B. G. Increasing the yield of corn by crossing. *In* Conn. Agr. Expt. Sta. Rpt. for 1916, p. 323–347. 1917.
47. Kansas Agr. Expt. Sta. Rpt. for 1917, p. 19, 23. 1918.
48. KEEBLE, F., and PELLOW, C. The mode of inheritance of stature and of time of flowering in peas (*Pisum sativum*). *In* Jour. Genetics, 1: 47–56. 1910.
49. KIESSELBACH, T. A. Recent developments in our knowledge concerning corn. *In* Nebr. Corn Imp. Asso. Ann. Rpt., 7: 15–42. 1916.
50. ——. Studies concerning the elimination of experimental error in comparative crop tests. Nebr. Agr. Expt. Sta. Research Bul. 13. 1918.
51. ——, and RATCLIFF, J. A. Freezing injury of seed corn. Nebr. Agr. Expt. Sta. Research Bul. 16. 1920.
52. KILLOUGH, D. T. Progress report of Substation Number 5, Temple, Texas. Tex. Agr. Expt. Sta. Bul. 215. 1917.
53. KYLE, C. H. Directions to cooperative corn breeders. U. S. Dept. Agr. Bur. Plant Indus. Pub. 564. 1910.
54. ——. Relations between yields and methods of selecting corn. Paper read before the Illinois Farm Advisers at Chicago, March 4, 1914.
55. ——. The relationship of early growth and the yield of grain in corn. *Abs. in* Jour. Amer. Soc. Agron., 8: 208. 1916.
56. LOVE, H. H. The relation of certain ear characters to yield in corn. *In* Proc. Amer. Breeders' Asso., 7: 29–40. 1911.
57. ——, and WENTZ, J. B. Correlations between ear characters and yield in corn. *In* Jour. Amer. Soc. Agron., 9: 315–322. 1917.
58. McCALL, A. G., and WHEELER, CLARK S. Ear characters not correlated with yield in corn. *In* Jour. Amer. Soc. Agron., 5: 117–118. 1913.
59. McCLUER, G. W. Corn crossing. Ill. Agr. Expt. Sta. Bul. 21. 1892.
60. MONTGOMERY, E. G. Experiments with corn. Nebr. Agr. Expt. Sta. Bul. 112. 1909.
61. ——. Correlation studies of corn. *In* Nebr. Agr. Expt. Sta. 24th Ann. Rpt., p. 108–159. 1911.
62. ——. Preliminary report on effect of close and broad breeding on productiveness in maize. *In* Nebr. Agr. Expt. Sta. 25th Ann. Rpt., p. 181–192. 1912.
63. MORROW, G. E., and GARDNER, F. D. Field experiments with corn, 1892. Ill. Agr. Expt. Sta. Bul. 25. 1893.
64. ——, ——. Experiments with corn. Ill. Agr. Expt. Sta. Bul. 31. 1894.
65. NOLL, C. F. Experiments with corn. Pa. Agr. Expt. Sta. Bul. 139. 1916.
66. OLSON, P. J., BULL, C. P., and HAYES, H. K. Ear type selection and yield in corn. Minn. Agr. Expt. Sta. Bul. 174. 1918.
67. Orange Judd Farmer. More McLean corn data. O. J. Farm., v. 63, no. 20, p. 1. Nov. 17, 1917.

68. PEARL, RAYMOND, and SURFACE, F. M. Experiments in breeding sweet corn. Maine Agr. Expt Sta. Bul. 183, p. 249–316. 1910.
69. PLUMB, C. S. Indian Corn Culture. Chicago: Breeders' Gazette print. 1895.
70. PRIDHAM, J. T. Report of plant breeder. *In* Rpt. Dept. Agr. N. S. Wales, 1914–15, p. 38–41. 1915.
71. ——. Report of plant breeder. *In* Rpt. Dept. Agr. N. S. Wales, 1915–16, p. 36–41. 1917.
72. RICHEY, F. D. The inequality of reciprocal corn crosses. *In* Jour. Amer. Soc. Agron., 12: 185–196. 1920.
73. RUSSELL, H. L., and MORRISON, F. B. Experiments in farming. Wis. Agr. Expt. Sta. Bul. 319, p. 11–16. 1920.
74. SANBORN, J. W. Selection of corn. Mo. State Col. Agr. Bul. 22, p. 5–6. 1886.
75. ——. Indian corn. *In* Agriculture of Maine, 33d Ann. Rpt. Maine Bd. of Agr., 1889–90, p. 78. 1890.
76. SCONCE, H. J. Scientific corn breeding. *In* Proc. Amer. Breeders' Asso., 7/8: 43–50. 1912.
77. SHULL, G. H. The composition of a field of maize. *In* Proc. Amer. Breeders' Asso., 4: 296–301. 1908.
78. ——. A pure line method of corn breeding. *In* Proc. Amer. Breeders' Asso., 5: 51–59. 1909.
79. ——. Hybridization methods in corn breeding. *In* Proc. Amer. Breeders' Asso., 6: 63–72. 1910.
80. ——. The genotypes of maize. *In* Amer. Nat., 45: 234–252. 1911.
81. SMITH, L. H. Ten generations of corn breeding. Ill. Agr. Expt. Sta. Bul. 128. 1908.
82. ——. The effect of selection upon certain physical characters of the corn plant. Ill. Agr. Expt. Sta. Bul. 132. 1909.
83. WIANCKO, A. T. The inheritance and effect of sucker production in corn. *In* Proc. Amer. Soc. Agron., 3: 51–58. 1912.
84. WILLIAMS, C. B. Economic value of corn suckers. *In* Proc. Amer. Soc. Agron., 4: 152–157. 1913.
85. ——, and ETHERIDGE, W. C. Characters of the corn plant associated with yield, and factors that influence them. *In* Proc. Amer. Breeders' Asso., 6: 237–244. 1910.
86. WILLIAMS, C. G. Pedigreed seed corn. Ohio Agr. Expt. Sta. Circ. 42. 1905.
87. ——. Corn breeding and registration. Ohio Agr. Expt. Sta. Circ. 66. 1907. Also, *In* Proc. Amer. Breeders' Asso., 3: 110–122. 1907.
88. ——. The selection of seed corn. Ohio Agr. Expt. Sta. Circ. 71. 1907.
89. ——, and WELTON, F. A. Corn judging: Studies of prominent ear characters in their relation to yield. Ohio Agr. Expt. Sta. Bul. 212. 1909.
90. ——, ——. Corn experiments. Ohio Agr. Expt. Sta. Bul. 282. 1915.

FIRST GENERATION CORN VARIETAL CROSSES.[1]

FRED GRIFFEE.[2]

INTRODUCTION.

The increased vigor of F_1 hybrids has been frequently noted from the time of the early hybridists, Gärtner and Köelreuter, until the present. The utilization of the vigor of an F_1 cross as a means of increasing the yield of corn was suggested by Beal (1)[3] of Michigan in 1876. The plan which he suggested was to import seed of a variety from various localities and to plant mixtures of these importations. In a report made in 1878, Beal (3) outlines the method which is commonly used today for the production of F_1 hybrid corn seed where quantity is desired. Yellow Dent corn was secured from each of two different counties and the two strains planted in alternate rows. All of one strain was detasseled before its pollen was shed and seed was selected from the detasseled rows. Beal held the Darwinian conception that the value from hybridization was due to the fact that the two strains entering the cross had been exposed to different conditions.

In 1880 (4), Ingersoll of Indiana, Henry of Wisconsin, Georgeson of Texas, and Gulley of Mississippi met with Beal at Michigan. All agreed to carry on an experiment testing the value of using hybrid seed. The fact that, excepting for a brief report by Ingersoll, Beal was the only one to report indicates clearly that little enthusiasm had been aroused for this method of increasing production.

Morrow and Gardner (17, 18) in 1892 and 1893 published the results of experiments in which the F_1 hybrids were definitely compared with their parents. Renewed interest was aroused by the publications of East (8) in 1908 and Shull (19, 20) in 1908 and 1909 on the effects of inbreeding and crossbreeding in corn.

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[3] Numbers refer to Literature cited, pp. 26–27.

Shull's pure line method of breeding was based on the hypothesis that a field of corn is composed of complex hybrids. Some of these hybrids are more heterozygous than others and consequently more vigorous. He advocated the isolation of pure lines by self-fertilization. These pure lines were then to be planted in alternate rows and all of one pure line detasseled. Seed for the general field was to be selected from these detasseled rows. Such hybrid seed would produce a field of corn in which every plant was heterozygous—that is, every plant would be as vigorous or more so than the most productive plants in the original mixed strain. Preliminary reports by Shull showed that some F_1 crosses were more vigorous than the original commercial variety.

Collins (6) believed, however, that the most advantageous combination might be found without first "reducing the varieties to the verge of extinction before the cross is made." East, while accepting the correctness of Shull's method from a theoretical standpoint, was inclined to the belief that F_1 varietal crosses had greater commercial possibilities.

The studies of Collins (6, 7), reported in 1909 and 1910, added materially to our knowledge of the value of first-generation hybrids in corn. The possibility was suggested that the use of the first-generation hybrid vigor might allow the extension of corn growing beyond the present area of production. Since hybrids grown at Washington, D. C., in 1910 remained dark green and vigorous when nearly all of the parental strains were showing signs of drought, Collins concluded that first-generation hybrids may be "relatively free from the new-place effects that so seriously interfere with the spread of varieties."

Since the first introduction of the method of utilizing hybrid vigor as a means of increasing yield in corn experimental tests have been made in most of the corn states. It is only within the last few years, however, that investigators have fully appreciated the value of careful field-plot technique. Many tests did not take into consideration the value of eliminating the effect of competition that may enter when varieties are grown side by side in single-row plots. The necessity of using replicated tests in order to overcome the harmful effect of soil heterogeneity has not been generally appreciated. In some cases the cross was compared with only one parent, and in many cases the experiments were carried for a single year only. In still other cases unadapted varieties were used.

Before making a review of F_1 crosses a brief statement of the

Mendelian hypothesis which most logically explains hybrid vigor will be given.

THE MENDELIAN EXPLANATION OF HYBRID VIGOR.

Since the discovery of linkage, or the fact that factors are inherited in groups, an adequate Mendelian explanation has been proposed which accounts for the increased vigor of an F_1 cross. East and Jones (9) in "Inbreeding and Outbreeding" give an excellent review of the development of this theory.

The theory assumes that varieties, which when crossed yield an increase in produce in the first hybrid generation, possess growth factors which are not common to both, and that these factors are partially or completely dominant over their allelomorphs. Thus, a factor pair will give more than half the stimulus to growth when in the heterozygous than when in the homozygous condition. Linkage of factors in inheritance explains why all favorable growth factors can not be combined in a homozygous individual. The only way to discover the best cross is to conduct field tests over a number of years, in which the hybrids compete not only with their parents, but with the best yielding variety for the locality in which the hybrid is to be grown. The increased vigor must be sufficient to pay for the extra labor of producing hybrid seed. That F_1 corn crosses frequently do give increased yields is evident from a summary of experiments which have been made.

PREVIOUS F_1 CROSSES SUMMARIZED.

In the following summary only those crosses which have been compared with both parents have been considered. Recent studies of the Minnesota station will be discussed in some detail later.

Morrow and Gardner (17, 18) in 1892 and 1893 tested nine F_1 hybrids, of which five exceeded the better parent in yield.[4] These tests consisted of a comparison in single-row plots of adapted varieties and their F_1 crosses. (See Table I.)

Collins (7) tested sixteen crosses of widely different types at Lanham, Maryland, and twelve outyielded the better parent. He also tested ten crosses between varieties of sweet corn at Washington, D. C. Of these, seven exceeded the better parent in yield. These results were based on single plot tests.

Hayes and East (12) in 1911 reported the results of three crosses in comparison with their parents. Two of the three crosses out-

[4] In the summary of previous F_1 crosses the term "yield" refers to yield of grain.

yielded the better parent. A later report by Hayes (11) compares twenty seven F_1 crosses with their parents. Fifteen of these crosses exceeded the better parent in yield. Adapted varieties were used for these crosses.

Hartley and others (10) conducted tests at Chico, California, and Waco, Sherman, and Corsicana, Texas. Sixteen crosses grown in California were made in Maryland and were not adapted to California conditions. Of these sixteen only four yielded an increase as compared with the better parent. In the Texas experiments adapted varieties were used and the tests were made at three stations. Results here given are averages of the three stations. Of the eleven crosses, four exceeded the better parent in yield.

Belling (5) tested a single cross in 1912. The cross yielded more than the better parent. He used one replication, but grew single-row plots.

Williams and Welton (21) used single plots and adapted varieties. They grew seven F_1 crosses, of which five exceeded the yield of the better parent.

Jones and others (15) made tests at two different stations. In all twenty-seven tests were made, in eighteen of which the F_1 cross exceeded its better parent in yield. These workers used adapted varieties, but single plots.

Kiesselbach of Nebraska (16) reports comparisons of ten crosses between late varieties. The average yield of these ten crosses was 1.97 percent less than the average of the parents. Kiesselbach also tested three crosses between early and late varieties. These averaged a 1.2 percent increase over the average of the parents.

Hutcheson and Wolfe (14) compared four F_1 crosses with their parents, one of which outyielded the better parent. These authors used adapted varieties and three replications.

These tests are summarized in Table I. In all 146 F_1 crosses have been briefly reviewed. Of these, 113 exceeded the parental average in yield of grain and 84 exceeded the better yielding parent. The percentage increase in yield over the average of the parents for the 146 F_1 crosses is 11.7.

These results certainly show that F_1 crosses on the average give increased yields as compared with normal varieties.

MINNESOTA RESULTS.

Hayes and Olson (13) summarized, in 1918, the results of a series of tests of F_1 crosses which had been carried on from 1915 to 1918, inclusive. Minnesota No. 13, which had been selected for ear type

TABLE I.—*Summary of comparative yields of first generation crosses and parents.*

Authority.	Location.	No. crosses tested.	No. crosses exceeding better parent.	No. crosses giving decrease from better parent.	Average percent increase or decrease from better parent.	No. crosses exceeding parental average.	No. crosses giving decrease from parental average.	Average percent increase or decrease from average parent.	Method of test.
Hartley, et al, 1912 (10)	Chico, California	16	4	12	− 2.5	13	3	+ 7.7	Single rows, unadapted.
Hayes & East, 1911 (12)	Mt. Carmel, Conn., 1911	3	2	1	+ 1.8	3	3	+28.0	Single rows, unadapted.
Collins, 1910 (7)	Lanham, Md.	16	12	4	+16.6	14	2	+53.0	Widely different types, 16 hills.
Collins, 1910 (7)	Washington, D. C.	10	7	3	+25.6	8	2	+81.0	Sweet corn, single plots.
Morrow & Gardner, 1892 (17)	Champaign, Ill.	5	3	2	+ 7.0	5	0	+14.0	Adapted varieties, single plot test.
Morrow & Gardner, 1893 (18)	Champaign, Ill.	4	2	2	− 1.2	3	1	+ 7.7	Adapted varieties, single plot test.
Hayes, 1913 (11)	Mt. Carmel, Conn., 1912	19	10	9	− 3.5	16	3	+10.1	Av. one replication, adapted, single rows.
Hayes, 1913 (11)	Mt. Carmel, Conn., 1913	8	5	3	+ 5.3	5	3	+ 8.3	Single plots, 3 rows, adapted.
Hartley, et al, (10)	Texas, Sherman, Waco, Corsicana	11	4	7	− .1	10	1	+ 9.8	Av. three test in dif. places, adapted, single rows.

TABLE I.—*Continued.*

Belling, 1912 (5)	Florida	1	1	.	+43.7	1	.	+48.0	Adapted varieties, single plots.
Jones, et el, 1916 (15)	Av. Mt. Carmel, Storrs, Conn.	9	6	3	+ 2.3	9	0	+ 8.5	Adapted varieties, single plots.
Jones, et al, 1916 (15)	Av. Mt. Carmel, Storrs, Conn.	8	3	5	− 3.0	5	3	+ 3.7	Adapted varieties, single plots.
Jones, et al, 1916 (15)	Mt. Carmel, Conn.	12	9	2	+ 4.2	11	1	+16.3	Adapted varieties, single plots.
Hutcheson & Wolfe, 1917 (14)	Blacksburg, Va.	4	1	3	11.2	3	1	+ 4.3	Av. three replications adapted, 4 row plots.
Williams & Welton, 1915 (21)	Ohio	7	5	2	+ .3	7	6	+ 3.2	Adapted varieties, single plots.
Hayes & Olson, 1919 (13)	University Farm, St. Paul	11	10	1	+11.7	10	1	+14.5	Adapted var. 2–4 yrs. test in dif. lots.
Kiesselbach, 1916 (16)	Nebraska	10	..	..	..	..	..	− 1.9	Adapted var. late var.
Kiesselbach, 1916 (16)	Nebraska	3	..	..	..	..	..	+ 1.2	Adapted var. early and late var.

for a period of several years prior to the test, was used as the male parent. Five flint varieties which were adapted to central Minnesota conditions were secured and an equal number of adapted dent varieties. Arrangements were made to secure seed of these varieties from the same growers each year. The F_1 crosses of the varieties here given were tested for a period of at least two years and in some cases for the four years from 1915 to 1918, inclusive.

Four rows, each 132 feet long, were used for each plot, the two central rows only being used for the yield tests. The various F_1 crosses were planted so that each was grown between its respective parents. Two or more systematically distributed plots were used for each variety and cross.

Of the five flint-dent crosses, four gave a significantly larger yield of bushels of shelled corn per acre than the better parent and one yielded slightly less than the parental average. The average increase in yield of bushels of shelled corn per acre of the F_1 flint-dent crosses over the better parent was 12.5 percent. The five dent crosses gave an average increase of 6.7 percent in yield of bushels of shelled corn per acre as compared with the better parent. Three of the dent varieties used were, however, somewhat too late in maturity for University Farm conditions and these crosses have not been further studied.

Rustler White Dent, which matures about the same time as Minnesota No. 13, has been grown at University Farm since 1915. During the last three years Minnesota No. 13 and Rustler Dent have been grown in isolated seed plots. Selection of seed for planting has been made at maturity from vigorous stalks in perfect stand hills. During the last two years those crosses which appeared most promising for the 1915 to 1918 test have been continued. In addition, crosses between Rustler and selected eight-rowed flints have been grown. For the period 1915 to 1920, inclusive, F_1 crosses between Minnesota No. 13 and the varieties Longfellow and Rustler have been tested each year. King Phillip × Minnesota No. 13 has been tested five years. Squaw Flint × Minnesota No. 13, Rustler × Longfellow, and Rustler × King Phillip have each been tested in the 1919 and 1920 seasons. Results of these tests will be considered in a little more detail.

A cross, Northrup King's Longfellow × Minnesota No. 13, was tested for the full six-year period. (See Table 2.) Four of the six years the cross yielded more bushels of shelled corn per acre than the better parent, one year the same as the better parent, and the remaining year somewhat more than the parental average. For the average

of six years it yielded 11.7 percent more in bushels of shelled corn per acre than the better parent.

While the cross of King Phillip × Minnesota No. 13 yielded more grain than either parent for each of the first three-year tests, it yielded slightly less in the last two years. For the five-year period, however, the cross exceeded the better parent by 8.8 percent in yield of bushels of shelled corn per acre.

TABLE 2.—*Comparative Yield of First Generation Crosses and Parents, 1915 to 1920 inclusive.*

Variety.	Yield in bushels per acre.							Yield percent No. 13 as 100.	Cross minus better parent.
	1915.	1916.	1917.	1918.	1919.	1920.	Avg.		
No. 13	21.8	54.2	....	47.9	70.1	33.0	45.4	100.0	
King Phillip	25.9	53.9	....	43.8	60.9	30.3	43.0	94.7	
Cross	32.6	63.3	....	52.6	68.6	30.1	49.4	108.8	8.8
No. 13	21.8	54.2	22.9	47.9	66.0	32.3	40.9	100.0	
Longfellow (N.K.)	29.8	48.1	22.1	47.4	58.5	26.2	38.7	94.6	
Cross	42.4	52.5	22.9	57.6	63.0	35.7	45.7	111.7	11.7
No. 13	....	....	....	....	70.0	30.4	50.2	100.0	
Squaw Flint	....	....	....	....	46.1	28.4	37.3	74.3	
Cross	....	....	....	....	72.8	36.0	54.4	108.4	8.4
Rustler	....	....	....	....	68.6	33.9	51.3	100.0	
King Phillip	....	....	....	....	58.6	30.5	44.6	86.9	
Cross	....	....	....	....	70.6	37.4	54.0	105.3	5.3
Rustler	....	....	....	....	69.2	36.0	52.6	100.0	
Longfellow	....	....	....	....	60.9	25.4	43.2	82.1	
Cross	....	....	....	....	74.1	35.6	54.9	104.4	4.4
No. 13	20.2	34.1	22.1	52.1	72.5	33.0	39.0	100.0	
Rustler	25.0	42.5	22.8	53.7	72.1	33.6	41.9	107.4	
Cross	26.7	45.1	22.7	49.9	75.7	38.1	43.0	110.3	2.9

Longfellow × Rustler for 1919 and 1920 exceeded the better parent in yield of grain by 4.4 percent. King Phillip × Rustler for the same two-year period yielded an increase of 5.3 percent over the better parent.

Rustler × Minnesota No. 13 yielded 2.9 percent increase in bushels of shelled corn per acre over the better parent. These two varieties have been grown from home-grown seed and since 1918 they have been selected for yield.

The cross between the early flint variety known as Squaw Flint and Minnesota No. 13 which was tested for the 1919 and 1920 seasons is of particular interest. The cross grew nearly as tall as Minne-

sota No. 13, showed the stooling ability of the Squaw Flint, produced ears nearly as large as Minnesota No. 13, yielded more grain per acre than Minnesota No. 13, and was a week to ten days earlier in maturity than Minnesota No. 13.

CONCLUSION.

The results of the test of F_1 crosses here reviewed are conclusive evidence that under present methods of corn breeding F_1 varietal crosses are a means of obtaining increased yields.

The correctness of present methods of corn seed selection, however, is problematical. Uniformity of ear type is the usual aim of the corn breeder. The result of University Farm tests of F_1 varietal crosses showed considerable larger increases in yield of shelled corn per acre in the earlier years of the study when Minnesota No. 13 was closely selected for ear type. However, even in recent years when selection in Minnesota No. 13 for yield alone has been practiced, the cross between Squaw Flint and Minnesota No. 13 has given 8.4 percent greater yield of shelled corn per acre than the higher yielding parent. Such a cross looks very promising for conditions where early maturity is a necessity.

LITERATURE CITED.

1. BEAL, W. J. Changing Seeds. *In* Mich. Bd. of Agr. Ann. Rept. 15: 206. 1876.
2. ——. Breeding Corn. *In* Mich. Bd. of Agr. Ann. Rept. 16: 56. 1877.
3. ——. The Improvement of Grains, Fruits, and Vegetables. *In* Mich. Bd. of Agr. Ann. Rept. 17: 454. 1878.
4. ——. Improving Indian Corn. *In* Mich. Bd. of Agr. Bienn. Rept. 1: 134–136. 1882.
5. BELLING, J. Hybrid Corn. Fla. Agr. Exp. Sta. Press Bul. 196. 1912.
6. COLLINS, G. N. Increased Yields of Corn from Hybrid Seed. *In* U. S. Dept. Agr. Year Book *1919*: 319–328.
7. ——. The Value of First-Generation Hybrids in Corn. U. S. Dept. Agr., Bur. Plant Indus. Bul. 191. 1910.
8. EAST, E. M. Inbreeding in Corn. *In* Conn. Agr. Exp. Sta. Ann. Rept. 31 & 32: 419–428. 1908.
9. ——, and JONES, D. F. Inbreeding and Outbreeding. 285 p. Philadelphia and London: J. B. Lippincott Company. 1919.
10. HARTLEY, C. P., BROWN, E. B., KYLE, C. H., and ZOOK, L. L. Crossbreeding Corn. U. S. Dept., Bur. Plant Indus. Bul. 218. 1912.
11. HAYES, H. K. The Corn Plant and Seed Selection. *In* Conn. Agr. Expt. Sta. Ann. Rept. 37: 353–390. 1914.
12. ——, and EAST, E. M. Improvement in Corn. *In* Conn. Agr. Expt. Sta. Bul. 168. 1911.

13. ——, and OLSON, P. J. First Generation Crosses between Standard Minnesota Corn Varieties. Minn. Agr. Expt. Sta. Tech. Bul. 183. 1919.
14. HUTCHESON, T. B. and WOLFE, T. K. The Effect of Hybridization on maturity and Yield in Corn. Va. Agr. Exp. Sta. Tech. Bul. 18. 1917.
15. JONES, D. F., HAYES, H. K., SLATE, W. L. and SOUTHWICK, B. G. Increasing the Yield of Corn by Crossing. *In* Conn. Agr. Exp. Sta. Ann. Rept. 40: 323–347. 1917.
16. KIESSELBACH, T. A. Studies concerning the elimination of experimental error in comparative crop tests. Nebr. Agr. Exp. Sta. Res. Bul. 13. 1917.
17. MORROW, G. E. and GARDNER, F. D. Field Experiments with Corn. Ill. Agr. Exp. Sta. Bul. 25. 1893.
18. ——. Experiments with Corn. Ill. Agr. Exp. Sta. Bul. 31. 1894.
19. SHULL, G. H. The Composition of a Field of Maize. *In* Amer. Breed. Assn. Ann. Rept. 4: 296–301. 1908.
20. ——. A Pure-line Method of Corn Breeding. *In* Amer. Breed. Assn. Ann. Rept. 5: 51–59. 1909.
21. WILLIAMS, C. G. and WELTON, F. A. Crossbreeding Corn. *In* Ohio Agr. Exp. Sta. Bul. 282: 100–103. 1915.

EAR-TYPE SELECTION AND YIELD OF DENT CORN.[1]

T. A. KIESSELBACH.[2]

The subject assigned the writer in this symposium was at one time of greater importance in the minds of agronomists and others than it is today. In the latter part of the nineteenth century a rather arbitrary a priori doctrine for ascertaining productive excellence of the seed ear was evolved from the mistaken line of reasoning that high shelling percentage and grain yield of the seed ear was synonymous with relatively high acre production. Thru associating this belief with the evolutionary teaching that like begets like, this ear-type perfection was to be preserved thru purity of breeding and selection for uniformity. Aside from the qualities denoting soundness of the grain, with its very obvious value, practically all of the points featured in the early score cards, devised as a guide for selecting seed ears, have their origin in the above reasoning.

These new teachings aroused great interest in corn and a number of station workers and practical corn growers planned experiments to

[1] Contribution from the Department of Agronomy, Nebraska Agricultural Experiment Station, Lincoln, Nebr. Read at the meeting of the American Society of Agronomy, Chicago, Ill., December 31, 1920.

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establish their significance. The outcome was to suggest that the physical ear characters of dent corn fall into two definite groups, those definitely nonutilitarian and those tending to be utilitarian. As an expression of progress in public sentiment, the tendency in some States has been to revise the corn score card, from time to time, attaching greater emphasis to important utilitarian considerations, such as adaptation and soundness. The other type considerations appear to be largely nonutilitarian, from the seed standpoint.

It may be observed that no score-card for judging competitive ear corn exhibits has yet been devised whereby nonutilitarian considerations are entirely eliminated and may not in many close cases determine the placing of awards. The Illinois score card of 1920 and the Nebraska score card of 1918 are outstanding in their subordination of nonutilitarian considerations. The former attaches about 80 percent of a perfect score to soundness, viability, and freedom from disease. The latter gave approximately 70 percent to soundness, viability, and adaptation.

The ear characteristics which have received chief consideration by corn enthusiasts are: 1, adaptation; 2, soundness; 3, maturity; 4, size of ear; 5, trueness to type; 6, uniformity of ears; 7, uniformity of kernels; 8, shape of kernels; 9, space between kernels; 10, depth of kernels; 11, total weight of grain; 12, shelling percentage; 13, shape of ears; 14, color of cobs; 15, color of kernels; 16, character of butts and tips of ears; and 17, straightness of rows.

The essential requirements of seed corn are that it shall be sound and that it shall be well adapted to the conditions where planted. The degree of adaptation depends upon the degree of harmony between the plant requirements and its environmental growth conditions. The highest degree of adaptation is regarded as that resulting in the maximum yield of sound grain per acre. The most pronounced environmental factors correlated with the growth habits of corn plants best suited for any region are climatic. Wide hereditary differences in native corn types are found in response to variation in climate. Thus, comparing adapted Lancaster Co., Nebr., corn with adapted Kimball Co., Nebr., corn, when both were grown under favorable conditions of Lancaster County, the former ripened 18 days later, produced plants which were 40 percent taller, bore the ears 150 percent higher above the ground, had 138 percent greater leaf area per plant, and produced 100 percent greater total dry matter per plant. The ears were 123 percent heavier, and had a 10 percent higher shelling percentage. These are inherited differences, which may be

ascribed primarily to the normal climatic differences of the two regions. Comparing the climate of Lancaster County with that of Kimball County, the normal temperature of the corn-growing season is 7° F. warmer, the frost-free period is 35 days longer, and the precipitation is 13 inches, or 81 percent, higher.

Plants of such differing growth habits commonly have distinct types of grain and ear. The special adaptation is more or less reflected in the ear. Smoothness and shallowness of grain, low shelling percentage, small ear circumference, and a low number of rows of grain per ear suggest relative earliness and small vegetative growth. Rough, deep grain, high shelling percentage, large circumference, and a high number of rows on the ear are rather characteristic of late maturity and large plant growth. In a general way, in response to adaptation, the more adverse the growing conditions are for corn, the more nearly does the corn approach the small stalk, low leaf area, slender ears, and smooth, shallow kernel of flint corn. This adjustment is often spoken of as "running out" of the corn, whereas it is an actual betterment for the prevailing conditions.

The so-called utilitarian ear characteristics have significance only in so far as they are linked with inherent vegetative growth habits of the corn plant. The exact nature of these plant characters and degree to which they will reproduce themselves can not be reliably judged by a mere examination of the ear. The correctness of such judgment is greatly enhanced by a previous knowledge of the source and purity of breeding of the corn. Thus, a small, smooth, shallow-grained nubbin of Boone County White grown in Indiana might very closely resemble an average ear of Marten White Dent corn which is well adapted to the short and dry season of western Nebraska. But if the two ears were planted side by side in Indiana, the one would produce plants about twice as large and five weeks later in maturing than the other.

It apears to be an almost universal practice on the part of the corn grower to pull somewhat against the natural law of adaptation by growing corn slightly too large and late for his conditions. This is in large measure brought about by an effort to approach the ear characteristics of corn grown in the most favorable corn districts of the country. This has been especially evident in the settlement of the western and northern frontiers of the corn belt. Newcomers found that the corn which they brought with them from more favored sections assumed more and more the dwarfish characteristics of adverse conditions. They believed their corn to be running out and replaced

it from time to time with imported seed, or selected for planting the ears which most nearly approached the original characteristics. Thru experience, however, the corn grower is coming to recognize the advantage of modifying his conception of ear type to harmonize with the environment of his locality. There is no such thing as a universal best type.

It is the purpose of this paper to present a brief digest of the available published data from the various agricultural agencies, including some unpublished results at the Nebraska Agricultural Experiment Station. It was thought that by bringing the important data together in this compact form, the reader would be aided in drawing his own conclusions. The experimental data are classified largely by States or institutions, since this avoids a frequent restatement of the methods or nature of the tests.

OHIO EXPERIMENTS.

Williams and Welton (18)[3] report results from the Ohio station as follows: In a 9-year test with three varieties, tapering ears outyielded cylindrical ears 2.3 percent in grain production (68.3 against 66.8 bu.). As an average for 7 years, smooth ears of the Clarage variety yielded 2.7 percent more grain than rough ears (65.3 to 63.6 bu.). Ears with bare tips having 1.2 inches of exposed cob yielded 0.3 percent less grain than ears with well-filled tips (62.4 to 62.7 bu.) as an average for 8 years.

During 10 years the long ears (averaging 9.2 inches) of four varieties exceeded the short ears (6.8 inches) by 2 percent in grain yield (69.5 to 68.2 bu.). In a 5-year comparison of 14-rowed and 18-rowed ears the former exceeded the latter 1.7 percent (60.9 to 59.9 bu.) at Wooster and 6.4 percent (57.6 to 54.2 bu.) at Germantown.

In a 6-year comparison of Clarage corn at Wooster, ears with high percent (88.2 percent) of grain yielded 0.6 percent less than ears of low (76.4 percent) shelling percentage (64.6 to 65.1 bu.). The shelling percentage of the ears grown from the two lots was 86.1 and 80.8 percent, respectively.

The Ohio experiments suggest a possible slight advantage for the long, slender, smooth ears, altho there is no very material difference between any of the types.

McCall and Wheeler (13) have calculated the coefficients of correlation for extensive ear-to-row tests between grain yield and the

[3] Reference by number is to Literature cited, p. 48.

length, weight, circumference, and density of the seed ears (Table 1). The yield tests cover seven years, 1905 to 1911, by the Ohio Agricultural Station and four years, 1906–1909, by J. W. Cook at Forrest, Ohio. No significant correlation was discovered.

TABLE 1.—*Correlation of ear characters and yield in corn. (McCall and Wheeler data).*

Array number.	Character.	Number of variants.	Coefficient of correlation.
I	Length	476	+.0580 ± 0.296
V	do	105	+.1017 ± 0.651
II	Weight	530	−.0270 ± .0292
VI	do	104	+.0866 ± .0656
III	Circumference	530	−.0968 ± .0287
VII	do	105	+.1803 ± .0636
IV	Density	526	+.0272 ± .0293

KANSAS EXPERIMENTS.

Table 2 presents data based on extensive ear-to-row tests, reported by Cunningham (3) of the Kansas Agricultural Experiment Station. The tests cover nine varieties during six years. Altho the ears planted were all of fair length, they were divided into three groups, long, medium, and short, for which the respective grain yields were 48.2, 48.4, and 48.2 bushels per acre. Ears having 16, 18, and 20 rows yielded, respectively, 43.5, 41.4, and 39.9 bushels per acre. This is 3.6 bushels between the extremes in favor of the 16-rowed ear. The small number of rows would seem to be correlated, to some extent at least, with small ear circumference. Ears with relatively large, medium, and small circumferences yielded 47.9, 49.3, and 49.6 bushels, which is 1.7 bushels in favor of the most slender ear. Ears with shelling percentages of 88, 86, 84, and 82 percent yielded 49.6, 49.9, 49.8, and 50.8 bushels per acre, respectively. The lowest shelling percentage yielded 1.2 bushels more than the highest. The yields of very rough, medium rough, and smooth-grained ears were 49.2, 52.6, and 53.5 bushels per acre, respectively, which is 3.3 bushels more for the smooth than the rough ears. Ears with well-filled, medium-filled, and poorly filled tips yielded, respectively, 51.7, 51.8, and 51.8 bushels per acre. Poor and partially rounded butts both yielded 51.0 bushels per acre compared with 50.7 bushels for well-rounded butts. Little relation between type and yield is shown by these Kansas data, aside from suggesting superiority for the rather slender, smooth ear of low shelling percentage.

TABLE 2.—*Relation of ear characters of corn to yield, as shown by ear-to-row tests at the Kansas station, 1905 to 1909 and 1912.*

Ear character.[a]	No. ears tested.	Length of ear, inches.	Circumference, inches.	Yield, bushels per acre.
Length of ear:				
Long	566	9.3	....	48.2
Medium	508	8.7	....	48.4
Short	363	8.1	....	48.2
Number of rows per ear:				
16	178	....	....	43.5
18	271	....	....	41.4
20	131	....	....	39.9
Circumference of ear:				
Large	335	....	7.36	47.9
Medium	552	....	7.01	49.3
Small	344	....	6.60	49.6
Shelling percentage:				
82	98	....	....	50.8
84	168	....	....	49.8
86	126	....	....	49.9
88	88	....	....	49.6
Type of indentation:				
Very rough	327	....	....	49.2
Medium rough	576	....	....	52.6
Smooth and wrinkled	343	....	....	53.5
Character of tips:				
Well filled	308	....	....	51.7
Medium filled	478	....	....	51.8
Poorly filled	216	....	....	51.8
Character of butts:				
Well rounded	346	....	....	50.7
Partially rounded	423	....	....	51.0
Not rounded	168	....	....	51.0

[a] Yields are to be compared only within each group and not between the different groups.

INVESTIGATIONS AT THE MINNESOTA STATION.

Extensive data from both ear-to-row and mass-selection tests have been reported from the Minnesota station by Olson, Bull, and Hayes (16). Altho comparative results are given for several localities, those from the University Farm alone will be given here, since these are, in general, confirmed by the other tests.

In the ear-to-row tests, ear types of Minnesota No. 13 corn were compared for five to eight years; Minnesota No. 161 types were tested for three to six years. The ears planted each year have been divided equally into two groups, representing opposites as to any one character. The results for the two varieties are shown in Table 3.

Ears with small circumference yielded 0.2 percent more than the ears of large circumference. The extreme variation in circumference was from 5.5 to 7 inches. Long ears averaged 1.3 percent higher grain yield than short ears. The ears varied from 6.25 to 8.75 inches

TABLE 3.—*Relation of ear characters of corn to yield, as indicated by data from ear-to-row tests of Minnesota Nos. 13 and 161 corn at the Minnesota station.*

Ear character.[a]	Minnesota No. 13.			Minnesota No. 161.			Average, bu. per acre.
	Duration, years.	No. of ears tested.	Yield, bu. per acre.	Duration, years.	No. of ears tested.	Yield, bu. per acre.	
Circumference of ear:							
Small	6	226	57.8	4	178	62.5	60.1
Large	6		57.6	4		62.4	60.0
Difference							.1
Weight of ear:							
Light	6	230	57.5	4	212	62.3	59.9
Heavy	6		58.1	4		62.5	60.3
Difference							.4
Shelling percentage:							
Low percent	6	232	57.6	4	175	62.9	60.2
High percent	6		58.1	4		62.3	60.2
Difference							0
Filling of tips:							
Poor	8	315	57.4	6	251	62.3	59.8
Good	8		57.6	6		62.7	60.1
Difference							.3
Filling of butts:							
Poor	8	298	57.5	6	250	62.7	60.1
Good	8		57.4	6		62.3	59.8
Difference							.3
Uniformity of kernel:							
Nonuniform	8	310	57.2	6	249	62.6	59.9
Uniform	8		57.5	6		62.2	59.8
Difference							.1
Varietal type:							
Least true to type	8	321	57.2	3	126	61.0	59.1
Most true to type	8		57.7	3		61.5	59.6
Difference							.5
Length of ear:							
Short	6	233	57.7	4	174	62.0	59.8
Long	6		58.3	4		62.9	60.6
Difference							.8
Total scorecard score:							
Low scoring	8	309	57.2	3	126	60.1	58.6
High scoring	8		57.9	3		61.0	59.4
Difference							.8
Maturity:							
Less mature	5	191	56.3	3	122	60.6	58.4
More mature	5		56.3	3		61.0	58.6
Difference							.2
Maturity:							
Scoring below 84 percent	4	137	57.2	3	122	59.1	58.1
Scoring above 84 percent	4		59.0	3		61.1	60.0
Difference							1.9

[a] Yields are to be compared only within each group and not between the different groups.

extremes in weight being 0.4 and 0.7 pound. Ears of high and low shelling percentage yielded equally, the shelling percentage ranging from 78 to 90 percent.

The difference in yield between ears with well-filled tips and those with poorly developed tips was 0.5 percent in favor of the former. Ears with poor butts produced 0.5 percent more grain than those in length. Heavy ears yielded 0.7 percent more than light ears, the classified as having good butts. Ears with uniform kernels yielded 0.2 percent more than ears with nonuniform kernels.

Ears most true to variety type excelled in yield by 0.9 percent, and those scoring highest as judged by the Minnesota score card yielded 1.4 percent more than the ears scoring lowest.

When classified into equal groups according to maturity of ears, the most mature yielded 0.5 percent more than the least mature group. When the ears were grouped according to whether they scored above or below 84 percent maturity, the ears with highest maturity surpassed by 3.3 percent.

In no case was there more than about a half bushel difference in yield between the one-third ears scoring highest in any one character and the one-third ears giving the highest total score as judged by the score card before planting (Table 4). In the majority of cases the slight difference in yield is against the ears with the highest total score.

TABLE 4.—*Data from ear-to-row tests of two varieties of corn at the Minnesota station, showing comparison of the one-third ears having highest total score with the one-third ears scoring highest in each individual character.*

Character.	Minnesota No. 13.[a]		Minnesota No. 161.[b]	
	Actual yield.	Deviation from highest total score.	Actual yield.	Deviation from highest total score.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*
Total score	58.3	....	61.3	....
Length	58.3	0	61.7	+0.4
Weight	58.4	+ .1	61.2	− .1
Circumference	57.9	− .4	62.0	+ .7
Shelling percent	58.2	− .1	61.5	+ .2
Butts	58.0	− .3	61.6	+ .3
Kernel uniformity	58.3	0	61.5	+ .2
Tips	58.3	0	61.9	+ .6
Variety character	58.7	+ .4	61.9	+ .6

[a] Eight-year averages.

[b] Six-year averages.

The coefficient of correlation was calculated for 9 different characters and yield, using 314 ear-to-row plats (Table 5). No significant correlation was found.

TABLE 5.—*Coefficients of correlation for various ear characters and yield, from ear-to-row tests conducted at the Minnesota Agricultural Experiment Station.*

Character.	Coefficient of correlation.	
Length	+0.098	±0.040
Weight	+0.047	±0.044
Circumference	—0.052	±0.041
Shelling percentage	+0.157	±0.043
Butts	+0.006	±0.037
Tips	+0.030	±0.038
Kernel uniformity	+0.048	±0.037
Variety character	+0.033	±0.037
Total score	+0.119	±0.038

Composite seed of 10 distinct ear types was planted in a comparative test during the years 1915 and 1916. As an average for the two years, ears of the show type were surpassed in yield by tapering ears, small ears, medium smooth ears, and ears with a low shelling percentage. The results are given in Table 6.

TABLE 6.—*Relation of ear type to yield in a bulk selection of Minnesota No. 13 corn grown at the Minnesota Agricultural Experiment Station, 1915 and 1916.*

Ear type.	Number of ears in test.	Yield, bushels per acre.	Deviation from show type, bu. per acre.
Show type	59	32.6	....
Long slender	71	31.8	−0.8
Short thick	92	31.9	−0.7
Tapering	72	34.6	+2.0
Cylindrical	39	30.2	−2.4
Small	80	33.1	+0.5
Rough	79	31.0	−1.6
Medium smooth	73	32.8	+0.2
High shelling percentage	34	32.1	−0.5
Low shelling precentage	34	34.4	+1.8

The Minnesota data, taken all in all, suggest that there is no dependable superiority of one ear type over another for seed purposes.

EXPERIMENTS IN ILLINOIS.

Sconce (17) reports 4-year tests on his farm with two varieties concerning kernel shape, germ size, and number of rows on the ear

(Table 7). The shape yielding lowest for one variety yields near the maximum for the other variety. Reid Yellow Dent ears having kernels with small germs yielded 3.8 bushels more grain per acre than ears with large germs. In the case of Johnson County White, the ears having large germs surpassed by 3.9 bushels. As an average for both varieties, yields from both germ types were practically equal.

TABLE 7.—*Relation of kernel size and shape to yield of corn, as shown by experiments of Sconce with Reid Yellow Dent and Johnson County White.*

Character.[a]	Yield in bushels per acre.											Ave. both varieties.
	Reid Yellow Dent.						Johnson County White.					
	1906.	1907.	1908.	1909.	1910.	Ave.	1907.	1908.	1909.	1910.	Ave.	
Size of kernel:[b]												
17 x 12	....	88.8	64.2	68.2	98.4	79.9	....	....	....	....	....	....
18 x 12	....	87.1	66.5	63.0	96.1	78.2	80.5	71.4	80.8	63.3	74.0	....
19 x 10	....	....	....	....	....	....	85.0	72.0	68.2	82.0	76.8	....
19 x 11	....	81.7	64.5	71.0	94.3	77.9	....	....	....	....	....	....
20 x 10	....	77.0	64.5	58.4	92.1	73.0	....	....	....	....	....	....
20 x 11	....	....	....	....	....	....	84.0	60.0	82.4	89.3	78.9	....
21 x 11	....	....	....	....	....	....	81.2	69.0	66.9	80.0	74.3	....
21 x 12	....	....	....	....	....	....	84.0	64.0	62.0	89.6	74.9	....
Germ:												
Large	....	79.4	62.8	66.0	97.3	76.4	86.7	68.1	75.7	86.7	79.3	77.8
Small	....	84.2	64.5	74.3	97.7	80.2	80.0	66.0	70.0	85.6	75.4	77.8
No. of rows:												
16	46.6	80.2	61.5	....	95.1	70.8	79.7	62.8	....	81.0	74.4	72.6
18	48.1	82.9	66.0	....	92.1	72.3	85.1	68.7	....	88.1	80.6	76.4
20	48.8	80.8	61.5	....	98.1	72.3	86.0	72.7	....	87.3	82.0	77.1
22	43.5	77.8	65.0	....	95.4	70.4	81.2	60.0	....	79.0	73.4	71.9

[a] Yields are to be compared only within each group and not between the different groups.

[b] Length and width in thirty-seconds of an inch.

Averaging both varieties, ears with 16, 18, 20, and 22 rows of grain yielded, respectively, 72.6, 76.4, 77.1, and 71.9 bushels of grain per acre. These figures suggest that ears with a medium number of rows are superior under Illinois conditions. Funk (4) has a number of times called attention to the superiority, under Illinois conditions, of more slender ears with smoother and shallower kernels than the prevailing corn show standards called for.

EXPERIMENTS AT THE CORNELL (N. Y.) STATION.

Love and Wentz (12) report five years' results from ear-to-row tests, which indicate that ears of low shelling percentage (81.1 per-

cent) yielded 9 percent more grain per stalk than ears of high shelling percentage (87.6 percent). Coefficients of correlation have been calculated for grain yield per stalk and various ear characters during the two years 1909 and 1910 with Minnesota No. 13 and Funk Ninety Day (Table 8) and with the latter variety (Table 9) during the five years 1910 to 1914. No dependable correlation with yield was found for any of the ear characters.

TABLE 8. —*Coefficients of correlation of ear characters with grain yield per stalk, derived from data from ear-to-row tests at the Cornell University Agricultural Experiment Station.*

Seed-ear characters correlated with yield per stalk.	Minnesota No. 13.		Funk Ninety Day.	
	1909.	1910.	1909.	1910.
Length	−.099 ± .076	.241 ± .064	.300 ± .061	.058 ± .067
Weight	.094 ± .076	.015 ± .068	.323 ± .060	.090 ± .067
Number of rows	.260 ± .072	−.127 ± .067	−.061 ± .069	−.034 ± .067
Weight of kernels	....	.028 ± .068	....	.043 ± .067
Ratio of tip circumference to butt circumference	....	−.162 ± .066	....	.014 ± .067
Percentage of grain	....	−.177 ± .066	....	....

TABLE 9.—*Coefficients of correlation of ear characters with grain yield per stalk of a strain of Funk Ninety Day corn, derived from data from ear-to-row tests at the Cornell University Agricultural Experiment Station during the five years from 1910 to 1914.*

Seed-ear characters correlated with yield per stalk.	Coefficient of correlation.				
	1910.	1911.	1912.	1913.	1914.
Length	.013 ±.067	−.013 ±.067	−.102 ±.069	.026 ±.067	.165 ±.066
Average circumference	.187 ±.065	.249 ±.053	.360 ±.061	.104 ±.067	.134 ±.067
Ratio of tip to butt circumference	−.037 ±.067	−.087 ±.067	.019 ±.070	.085 ±.067	−.131 ±.067
Average circumference of cob	.169 ±.066	.126 ±.066	.274 ±.064	.130 ±.066	.185 ±.066
Weight	.023 ±.067	.108 ±.067	.249 ±.065	.156 ±.066	.099 ±.067
Percentage of grain	−.102 ±.067	−.173 ±.065	−.051 ±.069	−.046 ±.067	−.183 ±.066
Average weight of kernels	−.105 ±.067	−.114 ±.067	.112 ±.069	−.152 ±.066	.082 ±.068
Number of rows	.113 ±.067	.097 ±.067	.083 ±.069	−.067 ±.067	.032 ±.068
Average length of kernels	....	.038 ±.067	....	....	−.043 ±.068
Average width of kernels	....	.162 ±.066	....	....	.065 ±.068

INVESTIGATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE.

Biggar (1) reports the relative yields from long and short ears of five varieties tested in ear-to-row tests for several years. The long

ears consistently yielded from 1 to 9 percent more than the short ears (Table 10). The coefficients of correlation were calculated for yield and ear characters of the same five varieties (Table 11). A slight positive correlation is indicated for weight and length of ear, while a very slight negative correlation is suggested for number of rows and shelling percentage.

TABLE 10.—*Relation of length of seed ears and yield of corn, as shown by data from ear-to-row tests of the United States Department of Agriculture.*

Variety.	Period of test.	Length of ears.		Relative yields.	
		Short.	Long.	Short.	Long.
		Inches.	*Inches.*	*Percent.*	*Percent.*
Selection 77	1914–1917	7.9	9.0	100	101
Selection 120	1915–1917	8.3	9.3	100	101
Selection 119	1915–1917	8.3	9.5	100	109
Selection 133	1912–1914	6.7	7.5	100	107
Selection 204	1916–1918	7.5	8.5	100	103

TABLE 11.—*Coefficients of correlation between yield and ear characters of corn, from data from ear-to-row tests of the United States Department of Agriculture.*

Variety and year.	Weight.	Length.	Number of rows.	Shelling percentage.
Selection 77:				
1914	+.085 ±.073	+.177 ±.071	+.046 ±.073	−.309 ±.066
1915	+.261 ±.065	+.067 ±.071	−.028 ±.070	−.028 ±.070
1916	+.188 ±.061	+.120 ±.064	+.025 ±.063	−.105 ±.063
1917	+.064 ±.072	+.133 ±.072	−.146 ±.071	+.001 ±.073
Selection 120:				
1915	+.200 ±.090	+.175 ±.091	−.266 ±.089	−.148 ±.091
1916	+.076 ±.083	+.001 ±.083	+.062 ±.082	+.276 ±.077
1917	+.200 ±.091	+.279 ±.090	−.025 ±.095	−.117 ±.093
Selection 119:				
1915	+.296 ±.074	+.231 ±.079	+.063 ±.081	+.067 ±.082
1916	+.131 ±.083	+.354 ±.075	−.147 ±.082	−.063 ±.084
1917	+.565 ±.061	+.330 ±.081	−.131 ±.088	+.155 ±.088
Selection 133:				
1912	+.070 ±.079	+.063 ±.080	−.077 ±.079	−.370 ±.076
1913	+.334 ±.072	+.381 ±.071	+.061 ±.081	−.017 ±.081
1914	+.130 ±.070	+.301 ±.066	+.015 ±.071	+.166 ±.069
Selection 204:				
1916	+.145 ±.093	+.082 ±.096	−.024 ±.095	−.368 ±.082
1917	−.074 ±.062	+.068 ±.064	−.040 ±.063	+.042 ±.063
1918	+.097 ±.075	+.276 ±.071	+.055 ±.075	−.263 ±.070

TESTS AT THE VIRGINIA STATION.

Hutcheson and Wolfe (7) offer two years' data from ear-to-row tests in support of the customary score card as a guide for selecting

high yielding seed ears. In all, 140 ear-to-row tests were made in 1916 and 98 tests in 1917. The yields from the 12 highest yielding rows in 1916 and the 9 highest yielding rows in 1917 are contrasted with the yields from the 10 lowest yielding rows of 1916 and the 11 lowest yielding rows of 1917 (Table 12). The ears harvested from these highest and lowest yielding rows were then scored according to the Virginia score card. As an average for the two years, the lowest yielding group fell 17.7 bushels per acre short of the highest group, which in turn conformed most nearly to the score-card requirements in nearly all particulars. The ear-to-row plats in this experiment consisted of two rows 66 feet long, which provide for a total of about 36 hills from each ear.

TABLE 12.—*Relation between yield and various seed ear characters of the crop harvested from the high and from the low yielding rows, in an ear-to-row test with Boone County White corn at the Virginia Agricultural Experiment Station, in 1916 and 1917.*

Character.	Measurement of score.		
	High yielding strains.	Low yielding strains.	Difference.
Yield per acre (bushels)	72.5	54.8	−17.7
Average length (inches)	8.5	8.0	− .5
Average circumference (inches)	6.8	6.6	− .2
Ratio of tip to butt circumference	.9	.9	0
Average circumference of cob (inches)	4.2	4.0	− .2
Percentage of grain	82.4	82.3	− .1
Average number rows	16.6	16.5	− .1
Average length of kernels (inches)	.4	.4	0
Uniformity of exhibits (percent)	52.2	48.1	− 4.1
Shape of ear and trueness of type (percent)	48.5	44.6	− 3.9
Character of tips (percent)	43.5	36.3	− 7.2
Character of butts (percent)	49.3	48.0	− 1.3
Uniformity of kernels (percent)	49.9	45.8	− 4.1
Shape of kernels and size of germ (percent)	52.6	47.0	− 5.6
Space between kernels (percent)	62.3	61.9	− .4
Space between rows (percent)	57.6	58.9	+ 1.3

In addition to the authors, Carrier (2) has interpreted these data as confirming the practical value of the score card in seed-corn selection.

There may be some doubt, however, as to whether the score-card differences indicated in Table 12 should be assigned as the underlying cause of this wide difference in yield. The superior score of the ears harvested from these high-yielding plats may, perhaps, be no more the cause than the effect of high yield. The causes may be entirely

foreign to ear-type considerations. Variations of as much as 5 percent in the perfection and uniformity of ear and kernel development and 25 percent in yield per acre may easily result from soil heterogeneity and stand variations within a series of 200 or 300 short corn rows. Any adverse environmental factor is likely systematically to reduce both the yield and score of an ear-to-row plat. The manner of comparison reported in this test does not appear to provide for the random and accidental distribution of inherently high and low scoring types in the field. The method employed permits the combination of any yield factors, and the most adverse combinations, whether seed or environmental, determine the opposing groups of plats. The more adverse combinations commonly result in the lowest scoring ears harvested.

In a test of this character it would appear that the aim sought could be best achieved by correlating the yield with the score of the corn planted, rather than the score of its progeny, and then comparing the yields from the high and low scoring types.

TESTS AT THE NEBRASKA STATION.

The early investigations at the Nebraska station regarding the relation between ear characters and yield were begun by Lyon in 1904 and continued till 1911 by Montgomery. A lot of rather long, slender, smooth ears with grains of only medium depth was selected from a general lot of Reid Yellow Dent corn harvested in 1904. The ears were grown in 1905 in comparison with the original standard Reid. During the three succeeding years this test was continued, selecting each year the long smooth ears grown from the long smooth ears of the previous year (14). As an average for the four years' test (Table 13), the long smooth type surpassed the standard type, with its greater circumference and rougher and deeper kernels, by 7.8 percent in yield.

TABLE 13.—*Average yield in bushels per acre obtained from long smooth ears of Reid Yellow Dent corn compared with the standard medium rough type of that variety at the Nebraska Agricultural Experiment Station during the four years from 1905 to 1908.*

Year.	Yield, bushels per acre. Smooth type.	Standard type.
1905	69.7	59.4
1906	47.2	51.4
1907	69.9	64.1
1908	56.8	51.2
Average	60.9	56.5

In 1909 five prize-winning show exhibits from Illinois, Indiana, and Ohio were compared for yield with ordinary corn of five varieties, obtained in Nebraska at a distance of fifty or more miles from the experiment station, and also with seven varieties secured locally. The show character of the seed from other States in no way offset the more important consideration of local adaptation (15). The average yields of these three lots of corn were, respectively, 39.8, 45.6, and 48.8 bushels per acre.

In 1910 five yellow and five white exhibits of good show type and five exhibits of poor show type were obtained from the Nebraska State Corn Show. When these three lots were compared for yield at the experiment station, they produced, respectively, 56.1, 55.8, and 56.9 bushels per acre.

In 1910 a number of Nebraska corn growers responded to a request to send to the experiment station samples of corn which they regarded as consisting of "good and selected" ears and other samples of "poor and run-down" ears. These were tested at the station and averaged 53.6 and 53.2 bushels, respectively.

During the three years from 1911 to 1913 a "high-yielding ear" contest was conducted in cooperation with the Nebraska Corn Improvers' Association. A large number of farmers each year entered an ear of corn which they regarded as a high-yielding ear. These were tested the following year by the experiment station, in an ear-to-row test, and the results were shown at the following corn show. The ears represented a great variety of types. It became evident from these tests that there was no dependable relation between type of ear and yield produced. For example, in 1911 an experienced corn show exhibitor won first premium at the State show on a single ear which was judged by the score card, while a similar ear which he entered in the high-yielding ear contest yielded the least of any of the 28 ears tested that year.

In 1917 the grand champion single ear and the grand champion ten ears of the State Corn Show were grown and entered by the same exhibitor, Glen Wilson, who is a young farmer residing about 50 miles northeast of the experiment station. In the season of 1917 both exhibits were tested at the experiment station in comparison with the growers' bulk seed from which the exhibits had been very carefully selected, and also in comparison with Hogue Yellow Dent corn which has never undergone any selection for a fixed type and consists of a great mixture of types. Wilson's grand champion single ear yielded at the rate of 45.6 bushels per acre, his State champion 10-ear

exhibit yielded 49.5 bushels, and his bulk farm seed yielded 50.8 bushels. In comparison, the Hogue Yellow Dent yielded 51.2 bushels. These results indicate that no yield improvement had been effected by selecting the high scoring types.

The butts, middles, and tips of Nebraska White Prize corn were compared (Table 14) during the four years 1914 to 1917 and yielded, respectively, 60.1, 60.7, and 61.7 bushels per acre. This suggests that all parts of an ear of corn have inherently about equal yielding power. In connection with this experiment, attention may be called to the statement by Miss Mary Lacy (10) summarizing all experiments to date (1915) on this subject: "In four out of eighty-one cases reported, we may be sure that the yield has been increased by the use of tip seed, and in the other cases there is no evidence that the use of tip seed has decreased the yield."

TABLE 14.—*Annual and average yields in bushels per acre obtained from butts, middles, and tips of Nebraska White Prize corn at the Nebraska Agricultural Experiment Station, 1914 to 1917.*

Seed planted.	Yield, bushels per acre.				
	1914.	1915.	1916.	1917.	Average.
Butts	48.8	77.0	65.0	49.6	60.1
Middles	48.0	76.8	68.8	49.4	60.7
Tips	49.6	75.3	69.3	52.7	61.7

During the four years 1914 to 1917 four distinct ear types were selected from the general variety of Nebraska White Prize corn and tested for yield (Table 15). Continuous type selection was not practiced in this test. The types were (1) large rough, (2) short rough, (3) short smooth, and (4) long, slender smooth. They yielded, respectively, 51.4, 57.1, 56.7, and 58.8 bushels per acre as a 4-year average. The original unselected corn yielded 58.1 bushels in comparison. The long, slender, smooth type of ear was the highest yielder and produced 14.4 percent more than the large rough type, but only 1.2 percent more than the original unselected corn. In this test the rough ear type planted had distinctly deeper kernels, larger ear circumference, and one-fourth more rows per ear. The characters tended to come true to type in the progeny, tho in a very marked lesser degree, as shown in Table 16, due to their complex germinal constitution resulting from promiscuous pollination.

TABLE 15.—*Annual and average yields in bushels per acre from different ear types of Nebraska White Prize corn at the Nebraska Agricultural Experiment Station, 1914 to 1917.*

Type of ear.	Yield, bushels per acre.				
	1914.	1915.	1916.	1917.	Average.
Original	48.7	64.8	65.5	53.5	58.1
Large rough	30.0	65.3	64.4	45.9	51.4
Short rough	44.4	68.9	65.1	49.9	57.1
Short smooth	45.0	72.6	60.1	49.2	56.7
Long slim smooth	48.7	66.4	65.2	54.9	58.8
Number of duplications	6	8	14	7	

TABLE 16.—*Relation of ear type to yield of a bulk selection of Nebraska White Prize corn grown at the Nebraska Agricultural Experiment Station. Four-year average, 1914 to 1917.*

Ear type.	Ear length.	Ear circumference.	Number of rows per ear	Ear weight.	Length of 100 kernels.	Width of 100 kernels.	Yield per acre.
	Inches.	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Bu.*
MEASUREMENTS OF EARS PLANTED.							
Long, large, rough	10.4	7.8	22	1.1	59	31	51.4
Short, large, rough	7.3	7.5	20	0.8	58	32	57.1
Short, slim, smooth	7.7	5.7	16	0.5	45	32	56.7
Long, slim, smooth	10.4	6.2	16	0.8	46	32	58.8
MEASUREMENT OF EARS HARVESTED.							
Long, large, rough	6.3	5.9	18.2	.36	49	33	51.4
Short, large, rough	6.3	5.9	17.8	.41	50	32	57.1
Short, slim, smooth	6.4	5.5	16.7	.37	47	32	56.7
Long, slim, smooth	6.8	5.6	17.4	.41	47	31	58.8

In 1916 and 1917 deep-grained rough ears and shallow-grained smooth ears of Hogue Yellow Dent corn (Table 17) were compared with unselected bulk seed of the same variety. The 2-year average yields were, respectively, 64.0, 69.6, and 64.5 bushels per acre.

TABLE 17.—*Relation of ear type to yield in Hogue Yellow Dent corn as shown by acre yields in bushels at the Nebraska Agricultural Experiment Station, 1916 and 1917.*

Ear type.	Yield, bushels per acre.		
	1916.	1917.	Average.
Deep rough kernels	72.0	56.0	64.0
Shallow, smooth kernels	80.1	59.2	69.6
Unselected	71.7	57.4	64.5

Further evidence of the undesirable nature of deep grained corn was secured indirectly in 1917. The ears harvested on December 29 from a field of Hogue Yellow Dent corn at the experiment station were divided into groups according to their apparent soundness, maturity, and solidity. These groups were tested for germination and the average length of kernel was determined for each (Table 18). Beginning with the most mature group, the germination for the five groups were, respectively, 93, 59, 14, 5, and 0 percent, and the corresponding kernel lengths were 0.49, 0.50, 0.52, 0.54, and 0.57 inch. On December 29 these groups contained, respectively, 15, 16, 19, 21, and 28 percent moisture. Corresponding groups at the time of the first killing frost, on October 8, 1917, contained 35, 39, 43, 47, and 50 percent moisture. The high moisture content is due to this having been an abnormal season for corn.

TABLE 18.—*Relation of kernel length to moisture content and freezing injury of corn when husked from the field during the fall and winter of 1917.*

Condition of corn at time of first frost, October 8.	Moisture in grain gathered on—		Germination of corn gathered on—		Length of kernel,
	Oct. 8.	Dec. 29.	Oct. 8.	Dec. 29.	Dec. 29.
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Inches.*
Fairly well matured and ears solid	35	15	98	93	0.49
Somewhat rubbery and ears twist	39	16	94	59	.50
Very rubbery and grain medium soft	43	19	92	14	.52
Grain very soft	47	21	92	5	.54
Late dough stage	50	28	82	0	.57

The Nebraska type studies indicate superior yields for shallower and smoother type selections than is customary in the more favored corn sections of the State. The sorts worked with were all standard full season varieties. I am not inclined to believe that this increased yield is due merely to the difference in ear type, but rather because it represents slightly earlier maturing and less rank growing plants.

Whether a corn grower may effect the greater improvement in the yield of his corn by selecting the smoother or rougher type of ear will probably depend upon whether his corn is now somewhat too small and early, or whether it is too late maturing and rank growing. In farm practice this adjustment of plant type to local conditions may be gradually effected by either selecting seed from the plants in the

field which possess the desired characteristics or else by selecting for seed those ears which suggest greater or less earliness and vegetative growth. In well-adapted corn it will probably prove advantageous to select for seed a mixture of ear types. Fancy ear considerations, such as perfect tips and butts, cylindrical ears, and uniformity of ears in size and shape, uniformity of kernels in size, shape, and indentation, and straightness of rows, are nonessential from the yield standpoint.

In general, for most Nebraska conditions at least, and probably for all regions not more favorably situated, distinctly deep-grained and rough ear types should be avoided. A distinct change in sentiment has in recent years taken place among some of our most prominent corn men in Nebraska, and they assert that experience has taught them to get away from the old-time rough, deep-grained corn and to follow a middle of the road policy.

EAR TYPE AND DISEASE.

It would appear that investigations of the root, stalk, and ear rot diseases of corn have not progressed sufficiently far to warrant conclusions regarding their significance in connection with ear-type performance. Disease may be one cause of rough, starchy, and chaffy kernels. But rough, starchy kernels are certainly not necessarily a criterion of disease. We probably can concede that the deep, rough, starchy kernel is at least as well adapted to the highly favored corn district of Franklin County, Ind., which is noted for its superb corn of this type, as some other type might be. Ears bearing evidence of disease or low viability should not be chosen for seed. The recent work of Hoffer and Holbert (5, 6) and others will doubtless stimulate more general investigations along these lines.

EXTREME UNIFORMITY OBJECTIONABLE.

In general, the principle of selecting for extreme uniformity in ear type or other plant characteristics is faulty. Corn is normally a complex and cross-fertilized crop. Artificial inbreeding of corn in which an ear is fertilized by pollen from the same plant greatly reduces the yield of the succeeding corn grown from the inbred seed. After four or five years of such inbreeding not more than one-fourth the normal production may be expected. The plants and ears, however, all come to be uniform in type. No one ever attains with his corn such a degree of purification of the germ elements by practicing rigid type selection, but there is a tendency to approach in a small

measure such purification and reduced production. The principle of broad breeding in which varied types enter into the constitution of the corn is correct.

A striking and unexpected occurrence of such reduced production by unconsciously restricting the seed to too great a degree of purity may be cited as follows: The Nebraska experiment station began ear to-row corn-breeding experiments in 1902. It was pioneer work and no one knew what was the best procedure to follow, so several plans were carried out and have been continued to the present. Of the 100 ears planted and tested individually for yield by the ear-to-row method, ear No. 64 surpassed all others. In order to avoid crossing with other and perhaps lower yielding ears, the remnant of ear No. 64 was planted off by itself the following year in an isolation plat. This procedure with strain No. 64 has been continued each year, with the result that, as an average for the seven years (1911–1917) when grown in a yield test with the original Hogue Yellow Dent corn, from which it was once selected as the premier, it has yielded 47.7 bushels as compared with 53.6 bushels per acre. This is practically a 6-bushel inferiority. In a comparable test in which four high-yielding ear-to-row strains were originally mixed together, and continued each year in an isolation plat, the yield has been nearly 1.4 bushels more than the original corn and 7.3 bushels superior to strain No. 64.

The Nebraska results from continued selection for high *vs.* low ratio of leaf area in proportion to dry matter may serve as a further illustration of unexpected reduction in yield due to continued type selection. During the seven years from 1911 to 1917 these two strains were compared with their F_1 hybrid as well as the original Hogue Yellow Dent from which they were selected. The strains originated from individual plants which differed in their amount of leaf area in proportion to dry matter. These characters had become fairly well fixed by continued selection for three years. They were thereafter grown in isolation plats, selecting each year well-developed ears from plants of the desired type. The low leaf area strain averaged 1,034 square inches per stalk and the high leaf area measured 1,340 square inches, while the original corn averaged 1,195 square inches of leaf area. Under comparable conditions during the seven years the yields of the low leaf area, high leaf area, original, and F_1 hybrid Hogue Yellow Dent have been, respectively, 51.9, 47.8, 53.4, and 53.5 bushels per acre.

As Olson, Bull, and Hayes (16) have also pointed out for the classical type selection by Hopkins and Smith in Illinois, for high and low oil and high and low protein, we may have an excellent example of reduced yield resulting from continued type selection.

Various degrees of closeness in breeding may be artificially effected. Results at the Nebraska Agricultural Experiment Station indicate that the closer the breeding, the smaller the yield. Thus, as a 7-year average, Hogue Yellow Dent corn which was

1. Inbred, yielded 16.8 bushels.
2. Narrow bred within a strain, 42.2 bushels (seed continued by single ear, fertilized by composite pollen from sister plants).
3. Broad breeding within a strain, 49.2 bushels (seed continued from composite ears, fertilized by composite pollen from sister plants).
4. Cross breeding between strains, 54.0 bushels.
5. In comparison with the above, the original wind-fertilized Hogue Yellow Dent corn has yielded 53.1 bushels per acre.

SUMMARY.

A review of the available data indicates that, within reasonable limits at least, variations in ear characters are rather neutral in their effect upon the yield of dent corn, except when they are definitely linked with special adaptive growth characteristics of the plant. Thus, slender ears with smooth, shallow kernels tend to be produced on earlier maturing, smaller, and less rank growing plants than are large, rough, deep-kerneled ears of the same variety. In the States of Kansas, Nebraska, Ohio, and Illinois, where the tendency has been to grow too large and late maturing corn types, selection of the rather long, slender, medium smooth ears, with kernels of medium depth and medium shelling percentage, results in somewhat increased production. Ear and kernel characters, aside from those known to indicate soundness and special adaptation, have little significance as indicators of high producing seed ears.

There are indications that close type selection, if long continued, may even reduce productivity, thru an approach toward gametic purity for the selected characters. This may also account in part for increased yields sometimes obtained from F_1 variety hybrids. Many institutions and individuals have practiced continued type selection in order to achieve uniformity and have perhaps unwittingly introduced an element of close breeding.

It has recently been proposed that the root, stalk, and ear rot diseases are somewhat associated with dull and starchy kernels and with

discolored or shredded shank attachment. Further and more general investigations may disclose the full significance of ear characteristics as disease indicators. The proposed control of these corn diseases opens a new and important field for investigation.

LITERATURE CITED.

1. BIGGER, H. H. The relation of certain ear characters to yield in corn. *In* Jour. Amer. Soc. Agron., 11: 106–113. 1919.
2. CARRIER, LYMAN. A reason for the contradictory results in corn experiments. *In* Jour. Amer. Soc. Agron., 11: 230–234. 1919.
3. CUNNINGHAM, C. C. The relation of ear characters of corn to yield. *In* Jour. Amer. Soc. Agron., 8: 188–196. 1913.
4. FUNK, EUGENE. Ten years of corn breeding. *In* Amer. Breeders Mag., 3: 295–302. 1912.
5. HOFFER, G. N., and HOLBERT, J. R. Selection of disease-free seed corn. Ind. Agr. Expt. Sta. Bul. 224. 1918.
6. HOLBERT, J. R., and HOFFER, G. N. Control of root, stalk, and ear rot of corn. U. S. Dept. Agr. Farmers Bul. 1176. 1920.
7. HUTCHESON, T. B., and WOLFE, T. K. Relation between yield and ear characters in corn. *In* Jour. Amer. Soc. Agron., 10: 250–255. 1918.
8. KIESSELBACH, T. A., and KEIM, F. D. The regional adaptation of corn in Nebraska. Nebr. Agr. Expt. Sta. Research Bul. 19. 1921.
9. KIESSELBACH, T. A., and RATCLIFF, J. A. Freezing injury of seed corn. Nebr. Agr. Expt. Sta. Bul. Research Bul. 13. 1920.
10. LACY, MARY G. Seed values of maize kernels; butts, middles, and tips. *In* Jour. Amer. Soc. Agron., 7: 159–171. 1915.
11. LOVE, H. H. The relation of certain ear characters to yield in corn. *In* Proc. Amer. Breeders' Assoc., 7: 29–40. 1912.
12. ——, and WENTZ, J. B. Correlations between ear characters and yield in corn. *In* Jour. Amer. Soc. Agron., 9: 315–322. 1917.
13. MCCALL, A. G., and WHEELER, C. S. Ear characters not correlated with yield in corn. *In* Jour. Amer. Soc. Agron., 5: 117–118. 1913.
14. MONTGOMERY, E. G. Experiments with corn. Nebr. Agr. Expt. Sta. Bul. 112, p. 19–24. 1909.
15. ——. Native seed corn. Nebr. Agr. Expt. Sta. Bul. 126. 1912.
16. OLSON, P. J., BULL, C. P. and HAYES, H. K. Ear type selection and yield in corn. Minn. Agr. Expt. Sta. Bul. 174. 1918.
17. SCONCE, H. J. Scientific corn breeding. *In* Proc. Amer. Breeders' Assoc., 7: 43–50. 1911.
18. WILLIAMS, C. G., and WELTON, F. A. Corn experiments. Ohio Agr. Expt. Sta. Bul. 282, p. 84–91. 1915.

VIABLE LEGUME BACTERIA IN SUN-DRIED SOIL.[1]

Wm. A. Albrecht.[2]

Instructions for the general practice of inoculating soils with *Pseudomonas radicicola* for new legumes by transfer of infected soil usually include the precaution that the infected soil must not be exposed to the sunlight (1), (2), (3), (4), (8).[3] It is generally believed that the organism is killed by such treatment or injured to such an extent that the soil will not serve effectively as inoculant for the legume crop on the new soil. It is sometimes recommended that the soil used for inoculation shall be scattered only on rainy or dark days, or that if used on a bright sunny day it shall be scattered in advance of some tillage operation (2) and worked into the soil immediately, since "the desirable bacteria are readily killed by exposure to the sun" (1). Such statements would lead to the belief that the organism is readily killed, and that the infected soil becomes worthless as inoculating culture by allowing it to dry in the sun.

The apprehension of this danger seems to have arisen from fancy rather than fact. It may have come from the general knowledge that sunlight is a good sterilizer, but evidently not from definite experimental work. To find out whether sunlight actually destroys the efficiency of infected soil as an inoculating agent, we have made some tests on soils used in a study of the longevity of *Pseudomonas radicicola*.

Four fertile silt loam soils, of two different soil types, each of which produced good crops of thoroughly inoculated red clover and soybeans one year, were collected in the following spring and divided into equal parts. One-half of each sample was spread out as a thin layer about ¼ inch deep in direct sunlight until thoroly dry, and then exposed for two months in a similar way on a bench in a greenhouse. The other half was taken into a dark room for drying. Both soils were later stored away from the light and heat, in sterilized jars, with every precaution against contamination, and then tested for their

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[3] Reference by number is to "Literature cited", p. 51.

ability to produce nodules on these two crops, as compared with the original soil left in the field.

To determine whether the *Pseudomonas radicicola* remained viable, soybean and red clover plants were grown in these soils within sterile bottles carefully handled to prevent the introduction of this organism from any other source. The production of nodules on plants grown from sterile seeds under such conditions would necessarily mean that the organism was living in the soil and had retained its power of infection. Approximately 750 grams of soil were put into wide-necked bottles of about 2-liter capacity, with inverted pint cups as covers; moistened with sterile water and planted with sterilized red clover and soybean seeds (7). From 2 to 4 plants of soybeans and 3 to 6 clover plants were grown in each bottle. After sixty days[4] the plants, tho small, were carefully removed by washing out the soil with running water and examined for nodules. As a check on the method plants were grown in sterile sand. These remained free from contamination.

The above test was repeated at intervals of six months for five times with the results given in the table:

Nodule Production in Soils with Different Treatments.

Soil Treatment.	Nodules per plant. Soybean.	Red Clover.
Dried in the sun and stored	5[5] (0–15)	8 (4–14)
Dried in the dark and stored	5 (0–14)	9 (2–22)
No treatment. Fresh field soil	9 (2–20)	10 (5–19)

From the above table it is evident that in the trials with the soybean organism there was a slight increase in the number of nodules produced with the decrease in the severity of the treatment, while for the red clover organisms there was less difference. The red clover thrives better under such adverse conditions as those existing in a closed container and bears many small nodules, but in case of both these legumes the growth was excellent and the plants were thrifty. The soil dried in the sun and that dried in the dark produced nodules on both kinds of legumes as well as the untreated fresh soil, hence the bacteria must have lived thru the treatment.

[4] In speaking of red clover Hunt (5) says, "Under greenhouse condition tubercules appear upon the main root in two weeks and upon the branches in four weeks." On basis of this statement sixty days were taken as time for plant growth to produce nodules.

[5] Figures are the averages from twenty bottles representing approximately a total of 64 soybean and 100 clover plants. Figures in parenthesis denote the range of numbers of nodules per plant.

In this method of testing soil for the presence of the legume organism—and at present it is the only method available—such numbers of readily visible nodules on plants so small indicate that the *Pseudomonas radicicola* was effective for inoculating the following seeding whether the soil containing it was dried in the absence or in the presence of direct sunlight, and that the dried soil stored for 30 months was as good for inoculating purposes as the fresh moist soil gathered from the field. These results indicate that direct sunlight and desiccation are not as destructive to this organism in its native habitat as has been stated (6), and that even tho some of the legume bacteria may be killed when the infected soil is exposed to the sun, the number of them so destroyed is not great enough to impair seriously the efficiency of such soil as an inoculating culture.

Literature Cited.

1. Brown, P. E. Soil inoculation Ia. Agr. Exp. Sta. Cir. 43, 3. 1918.
2. Coe, H. S. Sweet clover, growing the crop. U. S. Dept. Agr. Farm. Bull.. 797, 28. 1917.
3. Hopkins, C. G. Nitrogen bacteria and legumes. Ill. Agr. Exp. Sta. Bull. 94, 327. 1912.
4. Hopkins, C. G. Soil fertility and permanent agriculture, Ginn & Co., Boston, 1910.
5. Hunt, T. F. Forage and fiber crops in America. Orange Judd Co., New York, 1911.
6. Marshall, C. E. Microbiology, 2nd edition. Blakiston's Son & Co., Phila., 1917.
7. Prucha, M. J. Physiological studies of bacillus radicicola of Canada field pea. Cornell Agr. Exp. Sta. Memoir 5, 10. 1915.
8. Williams, C. G. Alfalfa culture. Ohio Agr. Exp. Sta. Mo. Bull., 175. June, 1917.

AN APPLICATION OF CLOSE BREEDING IN CORN WHICH PRODUCED NUMEROUS ALBINOS.[1]

A. N. Hume.[2]

In South Dakota Bulletin 186 it was attempted to set down some definite procedure for laying out a corn-breeding plot that should conform as nearly as possible to known principles, and also be practicable in farm management. It is admittedly a task to know all principles

[1] Contribution from the South Dakota Agricultural Experiment Station, Brookings, So. Dak., for publication September 12, 1921.

[2] Agronomist and superintendent of substations.

involved, and it is a puzzle to observe those principles in offering a practical plan to corn growers whereby they can depend on securing strains of corn bearing, for example, "determiners" of high yield.

The writer is attempting to develop "All Dakota" corn by applying a system of (1) continuous selection, (2) hybridization, (3) introduction of promising new strains. The present season is the sixth year for the breeding plot under discussion, and up to the present "All Dakota" appears to have developed favorably to the system.

It is of importance to develop a "variety" of corn for any given state. It is more important to define the steps that are essential practically from the standpoint of actual corn growers. For instance, is continuous selection essential in practical corn breeding? If so, in what respect?

The occurrence of albinos in certain rows of our "All Dakota" breeding plot this season may have some bearing upon this and similar questions. These albinos appeared within certain rows, which were collectively intended for the introduction of ears representing strains from outside sources. All of the albinos, however, appeared in the "sire" rows, which had been planted with kernels from either one of two ears, numbered, respectively, 19– and 21–. These two ears (more accurately the kernels borne by them) carry identical hereditary factors so far as our record can show. Moreover, both are close-bred ears (kernels) from the same "sire" row of "All Dakota" breeding plot of 1920. The pedigree of both ears is indicated by the following arrangement of ear numbers:

19– and 21–	414	392	248	112
				174 (S.D. 86)
			296	140
				188
		302	298	140
				198 (S.D. 86)
			202	188
				104
	414	392	248	112
				174 (S.D. 86)
			296	140
				188
		302	298	140
				198 (S.D. 86)
			202	188
				104

Both produced numerous albinos this year (1921), and there happened to be no other albinos in the plot.

Albinism is apparently forced to show itself as a result of close breeding or inbreeding. Would it not follow that the surviving selected progeny of inbred or close-bred ears (kernels) would be comparatively freer from the "genes" of albinism; and in like manner freer from other fatal or undesirable "genes"? Accordingly, would not the close-bred seed corn from "sire rows" be especially valuable in a succeeding year, for the reason that it is strongly "homozygote," and thus able to produce hybrid seed when crossed in a following generation?

Some of the considerations just set down may reinforce the idea that the usual prejudice against inbreeding and close breeding in *corn and gregarious animals* is founded on the apparent ill effect of such breeding upon immediate progeny, even tho such breeding in the long run may be beneficial to the race, by forcing undesirable "genes" to be eliminated.

BOOK REVIEW.

Breeding Crop Plants. *By H. K. Hayes and R. J. Garber. McGraw-Hill Book Co., New York, 1921, pp. 328.*—This book is one of the "Agricultural and Biological Publications" edited by Charles V. Piper. It will be of unusual interest and great value to agronomists, plant breeders, plant pathologists, and all students of economic botany, especially those directly interested in crop improvement. There have been available several text and reference books on genetics and plant breeding published in English, but heretofore Früwirth's "Die Zuchtung der Landwirtschaftlichen Kulturpflanzen" has been the only available reference work on the breeding of crop plants.

The style in which the book is written is clear and pleasing, and because of the well-chosen and logically arranged subject matter the book will undoubtedly prove a most welcome and useful text for courses in crop breeding or crop improvement. Particularly is this true since the work here reviewed is the first American or English book on the subject. A few typographical and other minor errors have crept in, but for the most part the physical make-up and presentation of the subject matter of the book are excellent.

The purpose of the book, as stated by the authors, is to outline methods of breeding in relation to the underlying principles involved and to present what are coming to be recognized as proper field methods of carrying on these studies, as well as to summarize the known facts regarding the mode of inheritance of many of the important characters of crop plants.

The book contains 66 text figures, 75 tables, a glossary, and a rather extensive bibliography. The subject matter is divided into 19 chapters.

In the Introduction attention is directed to the work of the early plant breeders, to the relation of certain biological principles to plant breeding, and to the value of crop improvement in relation to a more efficient agriculture. The chapter on Plant Genetics reviews genetic principles in some detail, tho the authors state that a previous knowledge of the principles of genetics is a necessity if the student of crop breeding is to pursue his work in the most logical manner. In the next chapter the important crop plants are grouped according to their pollination habits, and an explanation of hybrid vigor is given. Under the heading, Field Plot Technic, the authors discuss the use of checks and replicated plots, the value of probable error in the interpretation of experimental results, and the effect of competition. The size and shape of plots, border effect, and climatic variations are also considered.

The chapter on Inheritance in Wheat includes an account of the behavior in heredity of the characters of the plant such as disease resistance, winter hardiness, stiffness of straw, and earliness. The inheritance of spike characters such as compactness, chaff color, presence or absence of beards, and seed characters, including color and texture, are given detailed consideration.

In succeeding chapters similar but somewhat less extensive discussions are presented of inheritance in oats, barley, rye, buckwheat, and rice.

In discussing Methods of Breeding Small Grains, the authors describe the system of record-keeping in use at the Minnesota Agricultural Experiment Station. The use of the methods of selection and of crossing in small grain breeding is also discussed. A brief account of the technic of harvesting and thrashing is added.

In the chapter on Selection with Self-fertilized Crops an historical account of the early work in pure line or pedigree selection is given, followed by examples of some of the more recent economic results of selection in wheat, oats, and other crops. Some of the results of crossing as a means of improving self-fertilized crops are presented.

The chapter on Maize Breeding describes the origin and species of maize. This is followed by a detailed account of the inheritance of characters, including endosperm characters and a discussion of xenia, plant characters, seed and ear characters, size characters, and chemical composition. In the section on corn improvement the following subjects are discussed in the light of recent experimental work: Relation of ear characters to yield; ear-to-row breeding; relation between heterozygosis and vigor; immediate effect of crossing on size of seeds; F_1 varietal crosses; and isolation of homozygous strains.

The chapter on Grasses, Clovers, and Alfalfa is rather brief, particularly that part of it dealing with alfalfa.

The material on Potato Improvement includes an account of the origin of the potato and description of the species, the inheritance of characters, the production of new forms, difficulties of obtaining crossed seed, improvement thru seedling production, and clonal selection.

Information on the Breeding of Vegetables is presented in a chapter which includes the results of breeding experiments with the following close-fertilized crops: peas, beans, tomatoes, and peppers. The vegetables which are cross-fertilized include the radish, beet, asparagus, and members of the mustard and cucurbit families. Less than a page is devoted to the material on the breeding of beets, including the sugar beet. The very interesting historical material on sugar-beet improvement in Europe is only briefly mentioned, and nothing is said of the rather extensive biometrical studies of Pritchard and Harris in this country.

The chapter on Fruit Breeding is complete enough to meet the needs of the general student of crop improvement, but is not intended to satisfy the requirements of those especially interested in the breeding of horticultural plants.

The concluding chapter deals with the Farmers' Methods of Producing Pure Seeds. The importance of the determination of better varieties adapted to the locality where grown is emphasized. Good seed, methods of seed production and distribution, seed certification, and practical methods of corn improvement are described.—J. H. P.

AGRONOMIC AFFAIRS.

CHANGE OF THE EDITORSHIP OF THE JOURNAL.

With the completion of Volume 13, C. W. Warburton retires from the editorship after a period of seven years of unselfish and untiring service in this capacity, during the first four of which he also served as the Secretary of the Society. During his editorship the JOURNAL has steadily grown in both the quality and the quantity of published material, until finally the restrictions imposed by the financial resources of the Society became the only limiting factor in the volume of material which could be published.

Mr. Warburton has turned over to the present editor nearly fifty MSS. of articles which were available for publication on January 1, 1922. A few of these have since been withdrawn by their authors, in the hope of securing earlier publication elsewhere. In the case of some others, some abridgment has been suggested by the Board of Editors, in order to make it possible to publish as many of these articles at as early a date as possible. The Executive Committee, as authorized at the New Orleans meeting, is now considering the feasibility of including advertising in the JOURNAL, as a possible means of increasing the funds available for printing. If this is done, it is hoped that the JOURNAL may be regularly issued twelve times each year, in such numbers of pages as will permit the prompt publication of papers received.

The present editor pledges his best endeavors to promote prompt and adequate publication of all matters which are appropriate to the pages of the JOURNAL, and urges the hearty cooperation of the officers and members of the Society to this end.

NOTES AND NEWS.

Professor C. A. Michels, formerly of the North Dakota Agricultural College, is now in charge of the teaching in Field Crops in the Department of Agronomy at the Massachusetts Agricultural College. J. B. Abbott is Extension Specialist in Soils and Crops, and M. O. Lanphear has been added to the same Department as resident instructor.

Dr. Wm. Frear, Vice-Director and Chemist at the Pennsylvania Agricultural Experiment Station since 1887, died suddenly of heart failure, at his home in State College, Pa., during the night of Friday, January 7, 1922. Dr. Frear was widely known for his research work in agricultural chemistry and in connection with the development of food definitions and standards.

CORRECTION IN THE DECEMBER ISSUE.

The graph presented as Fig. 19, on page 346 of the December (1921) issue of the JOURNAL was accidentally printed upside down. In order that the matter should be properly shown, the diagram should be rotated thru an angle of 180°.

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SOME OBSERVATIONS ON THE BEHAVIOR OF BEARDED AND SMOOTH WHEATS[1]

By A. E. Grantham.[2]

In our work at the Delaware Station during the past twelve years considerable attention has been given to the testing of varieties of wheat. An effort was made to analyze more carefully some of the causes for the difference in yield of the varieties, particularly with reference to bearded and smooth wheats. As an outcome of this work it was found that the bearded wheats tiller somewhat more freely than the smooth, as was reported in Bulletin No. 117 of the Delaware Station. Following up this same work it was shown in Bulletin No. 121 entitled, "Wheat Investigations — Varieties," that the bearded wheats in previous tests averaged 3.3 bushels more than the smooth.

In studying varieties of wheat, it has been the custom to grow them on fertilized and on unfertilized land the same season. Even on the fertility plats where different carriers of plant food were applied, two varieties were grown on each plat, so that careful attention could be given to the variation which might occur between these two types. Our special investigations on wheat have given us the opportunity not only to compare the tillering habit and yield of wheat, but also to note the difference in quality. As a measure of the difference in quality, we have adapted the method of weight; that is, the relative quality of two varieties as indicated by the number of kernels required to weigh 10 grams. These were always taken from the ungraded grain.

[1] Read at the Chicago meeting, November 11, 1919. Received for publication, May 14, 1921.

[2] Formerly agronomist, Delaware Agricultural Experiment Station.

The results given in this paper have been secured in various ways

TABLE 1.—*Effect of fertilizers on the size of kernel in bearded and in smooth wheat. 1912 and 1916.*

Number varieties.	Number kernels in 10 grams. Fertilized.	No fertilizer.	Difference	Percent shrinkage
	1912			
Smooth — 34	330	422	92	21.7
Bearded — 26	310	343	33	9.6
	1916			
Smooth — 33	265	292	27	9.2
Bearded — 47	263	272	9	3.3

during the past 6 or 8 years. Table 1 shows the size of kernel on fertilized and unfertilized land, as the average of 60 varieties of wheat, 34 smooth and 26 bearded, for the year 1912. It will be noted that the average of the 34 smooth varieties was 330 where fertilizers were used. Where the land was untreated 422 kernels were required to weigh 10 grams, or a difference of 92 kernels additional to make the given weight where no fertilizers were used. In the same test the 26 bearded wheats gave 310 kernels per 10 grams on the fertilized land and 343 on the unfertilized, or a difference of 33 kernels more required for the given weight. It will be noted that about 3 times as many kernels were required to make up the difference due to lack of fertilizer in the case of the smooth. The same table shows the result of 80 varieties of wheat grown in 1916. Thirty-three of these varieties were smooth, which averaged 265 kernels per 10 grams under fertilizer, and 292, where no fertilizer was used. The 47 bearded varieties in the same test made an average of 263 kernels per 10 grams on the fertilized land and 272 for the untreated. In this case there were 3 times as many kernels required to make up the deficiency in the case of the smooth wheat as there were of the bearded.

Table 2 gives the average number of kernels in 10 grams for five varieties of bearded wheat and five varieties of smooth grown with and without fertilizer, during the years 1911 and 1912. In the case of the fertilized wheats the average is the result of 6 fertilized plats each season, and the untreated the average of four plats. The difference in number of kernels between the treated and untreated land in the bearded wheat was 41. In the case of 5 smooth wheats the difference was 72. Thus showing that the smooth wheats were more seriously affected by lack of fertilizer than the bearded.

TABLE 2.—*The variation in the size of kernel as affected by fertilizers in ten varieties of wheat. 1911 and 1912.*

	Varieties.	Kernels in 10 grams. No fertilizer.	Kernels in 10 grams. Fertilizer.	Difference.	Percent shrinkage.
Bearded	Farmers' Friend	320	271	49	15
	Gypsy	422	382	40	9
	Lehigh	339	299	40	12
	Turkey Red	437	405	32	7
	Velvet Chaff	425	378	47	11
	Average	388	347	41	10
Smooth	Dawson's Golden Chaff	482	384	98	20
	Early Ripe	393	312	82	20
	Fultzo-Mediterranean	402	371	31	7
	Gold Coin	478	379	99	20
	Mealy	502	449	53	10
	Average	451	379	72	15

Table 3 gives the results secured from planting two varieties of wheat, one bearded and the other smooth, on fertilized and unfertilized land, seeded at intervals of one week from September 17 to October 29. The smooth variety was the Red Wave, and the bearded, the Miracle. The fertilizers have a decided effect upon the quality of the grain and it will be noted that the quality of the smooth wheat deteriorated more rapidly with the later dates of seeding than did the bearded, particularly where no fertilizer was used. The uniformity of the size of kernel of the bearded variety where fertilizer was used is significant. This is in strict accord with other findings in our work that the bearded wheats seem to have the capacity for utilizing the plant food to better advantage, particularly where this material is not so rapidly available. This is shown by the more uniform quality of the bearded wheat under different dates of seeding where no fertilizer was used.

TABLE 3.—*The effect of time of seeding and fertilizers on bearded and smooth wheats.*

Date of seeding.	Number of kernels in 10 grams. Fertilizer. Bearded.	Fertilizer. Smooth.	No fertilizer. Bearded.	No fertilizer. Smooth.
September 17	234	340	354	442
September 24	236	362	405	483
October 1	247	351	380	514
October 8	245	338	427	515
October 15	269	323	484	466
October 22	315	425	464	637
October 29	317	420	552	604

The question may naturally arise as to the average size of kernel of the varieties under question. Under normal conditions there is very little difference in the size of kernel between the two. For example, graded grain of either variety will run about the same number of kernels per given weight.

In studying this table it is well to note the extreme variation which occurs in the bearded and in the smooth variety under the different dates of seeding. This gives some idea of the spread in quality. For example, the smooth wheat without fertilizer ranged from 442 to 637 kernels in 10 grams. The bearded ranged from 354 to 352. It should be borne in mind, however, that the quality of the smooth wheat was much lower even at best than that of the bearded. Where the two were fertilized the smooth shows a variation of 323 to 425, a range of 102, while the bearded wheat under fertilizer shows a range of 234 to 317, a range of 83 kernels, altho the heaviest kernels of the bearded numbered 234 in 10 grams, as compared with 323 for the smooth under the same conditions.

The preceding tables indicate that fertilizers play an important part with reference to the quality of the grain, and that the bearded wheats seem to respond to it more rapidly than do the smooth.

TABLE 4.—*Effect of fertilizers on the size of kernel in wheat. 1919.*

Treatment.	Number kernels in 10 grams.		Difference.		Percent.	
	Bearded.	Smooth.	Bearded.	Smooth.	Bearded.	Smooth.
Nitrogen	343	684	117	416	51	150
Phosphoric acid	344	496	118	228	51	81
Potash	340	380	114	112	47	40
Nitrogen and phosphoric acid	337	552	111	284	47	102
Phosphoric acid and potash	245	268	19	......	7	......
Nitrogen and potash	287	400	61	132	26	17
Nitrogen, phosphoric acid and potash	226	283	......	15	......	5
Nothing	347	514	121	248	51	92

Table 4 gives the size of kernel for a bearded wheat, Rudy, and a smooth wheat, Leaps Prolific, for the year 1919, with both varieties grown under the various treatments indicated. From this table it will be noted that the best quality of the bearded wheat was 226 under complete fertilizer. The poorest quality was 347 on the check plat. In the case of the smooth wheat the best quality was on the plat receiving phosphoric acid and potash, 268 kernels as compared with 684 where nitrogen alone was used. It will be noted that wherever nitrogen was used (unless supplemented by phosphoric

acid and potash) the kernels, especially in the case of the smooth wheat, were lessened in quality. This is in accordance with the facts commonly noted, that an excess of nitrates will often cause wheat to shrivel badly. The significant factor of this experiment is that the spread in quality of the bearded wheat was far less than that in the case of the smooth. The column headed " difference " represents the difference between the highest quality wheat of both bearded and smooth as compared with that of the other treatments. Thus 117 under nitrogen, represents the difference between 226 and 343.

TABLE 5.—*Size of kernel from bearded and smooth wheats taken on Delaware farms. 1919.*

Number of kernels in 10 grams

Bearded.	Smooth.
250	574
284	512
292	440
308	368
330	408
260	380
356	432
268	346
286	482
266	358
254	300
298	392
256	324
272	396
240	408
312	412
232	384
250	436
400	546
290	404
298	358
Average 285	412

Table 5. Soon after harvest during the past summer (1919) there was a wide comment that the wheat was not well filled, altho the production of straw was greater than usual. The writer had the opportunity of visiting a large number of fields in various parts of the State from which he took samples, wherever possible, of bearded and of smooth wheats grown under the same conditions of tillage and fertilization. Table 5 shows the number of kernels per 10 grams of these samples of bearded and smooth wheats taken on the same farm, and sometimes from the same sheaf. The lower part of the table shows more or less miscellaneous samples, for example, where a bearded or smooth wheat was taken from adjacent

farms or in the same neighborhood. In only a few cases were the smooth wheats of as good quality as those of the bearded. In these few cases it appeared that the proper balance of plant food had been applied, which accounted for the better quality of the smooth kernels. Wherever an excess of nitrogen is applied it seems to affect the smooth wheats more adversely than the bearded.

SOME METHODS OF RECORDING DATA IN TIMOTHY BREEDING.[1]

Morgan W. Evans[2]

Certain methods of obtaining records, which have been used during the past few years in connection with timothy breeding experiments, are described in this paper to illustrate the advantage of substituting quantitative data for those which are merely the results of general observations. For several years past the writer has been engaged in timothy breeding investigations, at the Timothy Breeding Station which is conducted cooperatively by the United States Department of Agriculture and the Ohio Agricultural Experiment Station, at Elyria, Ohio. The breeding of timothy is a phase of experimental agronomy which is of very recent development. Many of the methods which are used in timothy breeding, consequently, have to be originated as the work progresses.

Method of Comparing Different Varieties of Timothy.

One of the important phases of work in the breeding of timothy, as well as of any other crop, is the comparison of different selections or varieties with one another. In the comparison of different varieties of timothy, one of the things to be determined is the relative yields of hay which they will produce. As the result of a number of studies by different investigators, working with various field crops during the past ten or fifteen years, quite reliable methods have already been developed for growing the varieties in experimental test plats, and for obtaining records of the hay yields in these plats. But such matters as the time of blooming, maturity, number of green leaves on plants, and length of stems, however, are likely to be recorded differently by different observers, unless definite methods are adopted.

[1] Contribution from the Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for Publication, December 30, 1920.

[2] Assistant Agronomist, Bureau of Plant Industry.

Time When Timothy Plants are in Bloom and Mature.

The earliness or the lateness of the plants of different varieties is an important characteristic to be studied when they are compared. Until the method described in the following paragraphs was adopted there was no way by which the degree of earliness or lateness of different varieties of timothy could be accurately measured.

The earliness or lateness of a variety of timothy is indicated quite largely by the time when the plants are in bloom and mature. In order to get definite records of the time when the plants are in these stages of development it is necessary to have definitions of the conditions of the plants when they are in bloom or mature. The term *plant* as related to timothy, is applied to all the shoots which have grown from a single seed, or from the detached vegetative part of another plant. Before the various stages of bloom can be defined for the plant, it is necessary to have a definition of a head in full bloom. The following one has been used:

A timothy head is in full bloom when flowers are in bloom throughout two-thirds or more of its entire length.

When a timothy head is passing out of the stage of full bloom, the boundary between the part of the head where the flowers are in bloom, and where they are not in bloom is usually not as well defined as on heads which are just coming into full bloom. The head can be considered in full bloom, however, when flowers in bloom are distributed over two-thirds or more of its total length, whether the area over which the flowers are blooming is, or is not, continuous.

The time during which a timothy plant is in bloom has been divided into four periods as follows:

Early Bloom. *A timothy plant is in early bloom from the time that the first flowers have bloomed until it is in full bloom.*

Full Bloom. *A timothy plant is in full bloom from the time that 25 per cent of all heads are in full bloom, and 25 per cent or more additional heads have begun to bloom, until 25 per cent of all heads are past full bloom and 25 per cent or more additional heads are past bloom through some portion of their length.*

Late Bloom. *A timothy plant is in late bloom from the time that it has passed full bloom until it is in very late bloom.*

Very Late Bloom. *A timothy plant is in very late bloom when all of the main crop of heads are entirely past bloom, and only a few small late heads, usually on short culms, remain in bloom.*

The condition of a timothy plant when mature is explained in the following definition:

A timothy plant is mature when all of the glumes have become straw

colored on 25 per cent of the heads, and more than half of the glumes have become straw colored on 50 per cent or more additional heads.

The records of blooming and maturing have usually been obtained from plants growing at a distance of 2.5 feet apart, in rows which are 3.3 feet apart. When the plants are in bloom, the records can can best be obtained early in the morning, as it is more difficult to obtain accurate records after the filaments of the anthers have become wilted by the sun and wind. When the plants are maturing, the records can be obtained at any time of the day. While records are made of each plant when it is in early, full, and late bloom, on each day when the plants are in bloom, the records of the time of full bloom only have been used when the data have been compiled. From the total number of plants in each plat, and from the number of plants in these plats which are in full bloom or mature on different dates, the percentage of plants in full bloom or mature on each date can be readily calculated. To illustrate the use of these definitions, our records show that in 1917 in a plat of timothy, No. 6162,[3] half of the plants were in full bloom 3 days earlier and matured 4 days earlier than were an equal proportion of the plants in a plat of ordinary timothy with which it was compared. In another plat, of selection No. 6779, half of the plants remained in full bloom 5 days later, and matured 6 days later than the ordinary timothy.

When there is any doubt whether a plant should be recorded in early bloom or in full bloom, it has been the practice to classify it in early bloom. Likewise, if there is some uncertainty as to whether a plant is in full bloom or in late bloom, it is classified with the plants in full bloom. In other words, no change is made in the daily records of a plant, from the stage of bloom in which it has been during the days immediately preceding, if there is any doubt whether the change should be made.

In each season, there are usually one or more days during the blooming period, when, because of unfavorable weather conditions, timothy flowers do not bloom. On such days it has been the practice to make no record at all of the condition of the plants.

Experience has demonstrated that the relative difference in the time of blooming, and of maturing, of any two varieties of timothy, one of which may be early and the other late, is approximately the same. In comparative studies of different varieties, therefore, records of the time when the plants are in bloom may be sufficient;

[3] The numbers used here belong to a series of numbers which have been assigned by the Office of Forage-Crop Investigations to different selections of timothy and other crops.

the records of the time when the plants mature can often be omitted, with no serious loss of data.

Through this system of recording notes it has been possible to present definite information in regard to how early or how late the timothy plants in plats of selections Nos. 6162 and 6779 bloomed and matured. By the same method it would be possible to obtain exact comparisons of these selections with other selections; or to determine accurately whether the relative times of blooming and maturing of plants of selections Nos. 6162 and 6779 are the same in any other season as they were in 1917. Without this system about all that it would have been possible to state, in regard to the earliness and lateness of the selections, would be that one bloomed and matured somewhat earlier and the other somewhat later than ordinary timothy.

One test of the value of any scientific method is its accuracy when employed by different persons working under various conditions. Obviously, it would not always be possible to determine whether a timothy plant should be considered in early bloom, or in full bloom, with the same exactness that a quantitative determination can be made in a chemical laboratory. Nevertheless, it has been found that the percentages of plants in early, full, or late bloom can be determined very closely. It is only a small proportion of the plants which an experienced observer has any difficulty in classifying. If a timothy plant is so nearly on the border line between the stage of early bloom and full bloom on any particular date, that two observers might classify it differently, usually by the next day when the flowers are in bloom, the numbers of flowers in bloom will have increased to such an extent that there will be no doubt about the plant being in full bloom.

In 1919 two observers, working independently, made records of the number of plants in full bloom in the same row plat of timothy.

TABLE 1.— *Percentage of timothy plants in full bloom, on different dates in 1919 in a row plat of 20 plants propagated vegetatively from the original plant of No. 9400. Results obtained by two observers working independently.*

Date.	Percentage of plants in full bloom as determined by observer.	
	A.	*B.*
July 1	90	95
2	90	95
3	95	95
8	25	30
10	10	5
11	5	5

These records are presented in Table I. This table shows that while there was a slight difference in the results, the general character of the curves that could be plotted from these data would be essentially alike. Results obtained by other observers in 1917 and 1918, indicate that the records obtained from the same plats by two experienced observers may be even more nearly identical than those presented in Table I.

The Relative Number of Green Leaves on Plants of Different Varieties.

Records which show how much earlier or later the flowers bloom and seeds mature, on plants of one variety of timothy than on the plants of another, do not usually tell the complete story of the relative earliness or lateness of the two varieties. It has been observed during the early summer months that, on any particular date, a larger proportion of the leaves are green on the plants of some selections than on others. In order to get accurate information in regard to this characteristic, a method has been developed for determining the number of leaves with blades which are either entirely or partially green, per unit of area, in broadcast plats or meadows of different varieties.

All stems were collected daily from June 25 to August 5, 1919, from two typical areas each 6 by 36 inches, in duplicate broadcast plats of ordinary timothy and of timothy No. 3937. Four sets of stem of plants of each variety were therefore examined each day. The samples were taken to the building on the Timothy Breeding Station and each was separated into two groups of stems — those with heads, and those on which no heads had developed. A record was then made of the number of stems of each type, and of the number of leaves with blades either entirely or partially green on each stem. It has been the practice to consider a leaf blade partially green as long as the tissue remains green across the entire width of the blade at its base, or as long as there is green tissue partially across the blade extending for one inch or more above the base of the blade. From these records, the average number of entirely and partially green blades per stem on each date was calculated: Then, in each of the duplicate plats of the two varieties, three typical square-yard areas were selected and a count was made of the number of stems with and without heads in each area. From the data obtained the total number of leaves with entirely or partially green blades per square yard, on each date, in plats of both varieties, was calculated in the following manner: The average number of stems with heads per square yard was multiplied by the average number

of leaves with entirely or partially green blades on stems with heads on any particular date; the average number of stems without heads per square yard was multiplied by the number of entirely or partially green leaf blades on these stems on that date; the total number of entirely and partially green leaves per square yard was obtained by adding the two products. The records obtained in 1919 are presented graphically in Figure 1.

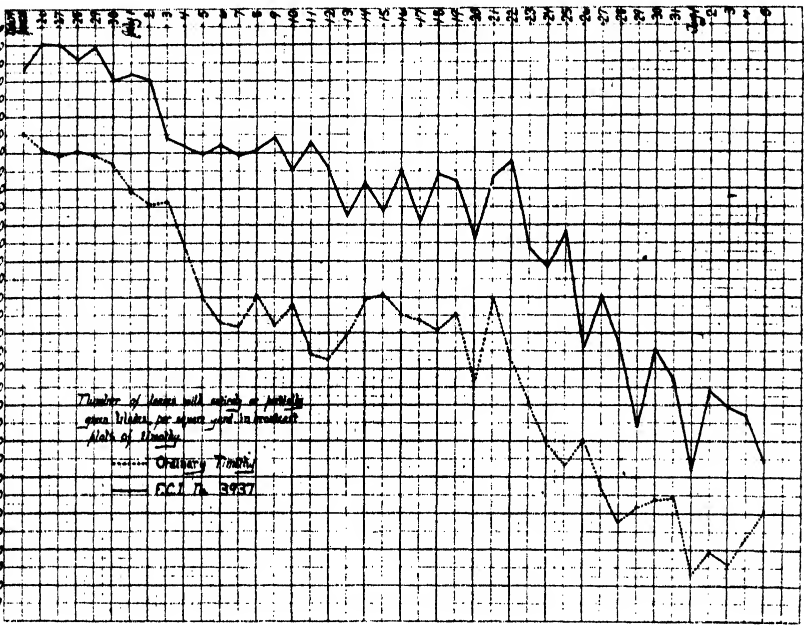


FIG. 1—Graph showing number of leaves with green or partially green blades, in typical square-yard areas in plats of ordinary timothy and of No. 3937, on different dates in 1919.

These records not only show that there may be more green leaves in a plat of one variety than of another, but also just how many more green leaves there are per unit of area in the plat of one variety than of the other. Considerably more time is required to obtain these records than those showing the degree of blooming and maturity. The time required for determining the relative numbers of green leaves in plats of different kinds of timothy could probably be reduced, and at the same time the efficiency of the method might be maintained or increased, if samples were collected at 5-day intervals instead of daily, and if somewhat more than two samples per plat were collected on each date. If from three to five samples had been

collected on each date in 1919, the curves in Figure 1 would probably show less irregular variations from day to day. If the number of samples were increased, it is possible that the size of the area from which they are collected could be made somewhat smaller than 6 by 36 inches, and thus the time required to obtain the records would be further reduced.

LENGTH OF THE STEMS OF PLANTS OF DIFFERENT VARIETIES OF TIMOTHY.

One of the conspicuous differences between some of the selections and varieties of timothy which have been studied, is that the stems of the plants of some are longer than those of others.

Timothy plants growing in cultivated rows produce a large number of stems. In order to determine their exact average length, it would be necessary to measure the length of all the stems in each row. This work would require so much time that the method would probably not always be a practicable one. It has been observed that in cultivated rows most of the stems of any one timothy plant usually grow to approximately the same height. Therefore, if the longest stem of each plant in a row is measured, from the surface of the soil to the tip of the head, the average length of these longest stems will quite nearly represent the average length of the stems of all plants in the row.

Records of the lengths of the longest stems of the plants in two row plats of timothy Nos. 6824 and 6839, and in one row plat of ordinary timothy, were obtained in 1917. These plats were located near one another, on uniform soil, and the plants had been grown under the same cultural conditions. This information is presented in Table II, which shows that the average length of the stems in the plat of ordinary timothy was slightly greater than in the plat of No. 6824, and was considerably less than in the plat of No. 6839.

TABLE 2.—*Average length of the longest stem of plants in row plats of timothy.*

	Inches.
Ordinary timothy	43.5
Timothy No. 6824	42.9
Timothy No. 6839	51.8

If these or other similar records are represented by graphs, they may show that the lengths of the stems of some selections are more uniform than the lengths of the stems of others. By calculating the average deviation from the mean length of the longest stems of the plants in each one of the plats, it would be possbile to express in quantitative terms the degree of uniformity of the lengths of the longest stems of plants of the different selections.

SUMMARY.

In timothy breeding, which is a comparatively new phase of experimental agronomy, standard methods have yet to be worked out and adopted. Several methods which have recently been developed for making comparative quantitative studies of different selections or varieties of timothy are described in this paper.

Through the use of certain definitions which describe timothy plants in different stages of bloom and maturity, it has been possible to obtain accurate records of the time when the plants of different selections or varieties of timothy are in bloom and mature.

A system of counting the number of leaves with partially or entirely green blades has been developed, by which the relative numbers of green leaves, per unit of area, on different dates in broadcast plats of different kinds of timothy, can be accurately determined.

By measuring the longest stem of each plant growing in cultivated row plats of different selections or varieties of timothy, it is possible to obtain data which show not only the relative lengths of the stems of the plants in the different plats, but which also show the relative degree of uniformity in the lengths of the stems of plants in the plats in which measurements are made.

SUNFLOWER STUDIES[1]

P. V. CARDON.[2]

I — VARIATION IN THE "MAMMOTH RUSSIAN" VARIETY.

The results of cultural experiments with sunflowers, as conducted since 1915 by the Montana Experiment Station, show the "Mammoth Russian" to be better as regards acre-yield of silage than any other variety tested. However, it is plain to all observers that there is little uniformity in the type of plants produced from the commercial seed of this variety and the possibility of developing superior strains must have appealed to everyone who is interested in selection for the improvement of the sunflower crop.

In Montana, a particularly urgent need for improvement in the sunflower crop arises as the result of varied conditions of soil and climate. In the high plateau regions of the western part of the state, where sunflowers seem to be especially well adapted, no seed can be matured because of the short growing season. This condition makes necessary the importation of seed from other regions. Good sun-

[1] Contribution from Agronomy Department, Montana Agricultural Experiment Station, Bozeman, Mont. Received for publication, April 17, 1921.

[2] Agronomist.

flower seed can be produced under irrigation in the lower altitudes of eastern Montana, and it may be possible to establish in that region seed supplies to meet the requirements of western Montana farmers. The problem, however, is to get a strain to satisfy both the seed grower of the east and the silage grower of the west.

The difficulty encountered in harvesting sunflowers which are so tall as they grow under irrigation in Montana, affords another practical reason for undertaking improvement work with sunflowers. A high producing strain possessing a relatively low habit of growth, which would facilitate the harvest of the crop by permitting free use of the corn binder, would be especially desirable.

It was in recognition of the foregoing requirements that the Agronomy Department of the Montana Experiment Station began its selection work with sunflowers in the spring of 1920. Although the results of only one season are available, they are suggestive of the possibilities with this crop.

For the reasons already given, the " Mammoth Russian " variety was used in this preliminary work. Identical plantings were made under irrigation at Bozeman, and on dry land at Huntley, Moccasin and Havre, each point being representative of a different combination of soil and climatic conditions. In each planting, there were 144 hills (checked) 3 feet apart, making a plot 39 feet square. Only the 100 plants inside the square were studied, the 12 outside plants on each side of the square being treated as controls. Since the 100 plants were equi-distant and all under practically the same environmental influences, it was assumed that their habits of growth were entirely the result of inherent tendencies. Seed from the same commercial lot was used at all four points, and enough seed sown in each hill to insure the presence of at least one plant. Later, only one plant was left to develop in each hill.

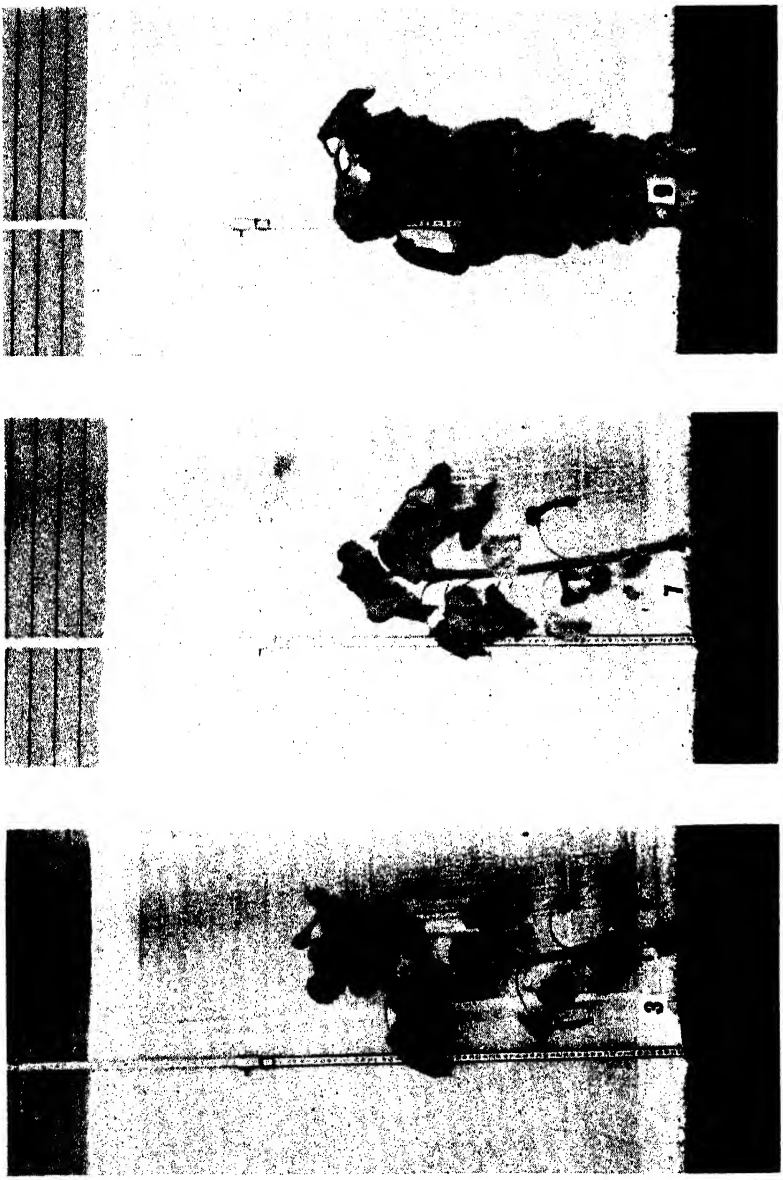
The plantings at Moccasin and Havre were seriously injured by drouth, but at Huntley and at Bozeman it was possible to make some interesting comparisons, as shown by the photographs presented herewith. [3] See Plates I, II and III.

At Huntley, on September 7, when most of the plants were in full bloom, 10 different types were distinguished. Later, it was found that two of these (No. 3 and No. 4) each comprised at least two sub-types, distinguishable on the basis of either seed color or earliness.

Following is a brief description of each type, with the percentage of plants it included, and a note as to maturity.[4]

[3] All of the photographs accompanying this article were taken by J. B. Nelson, Field Superintendent, Agronomy Department, Montana Experiment Station.

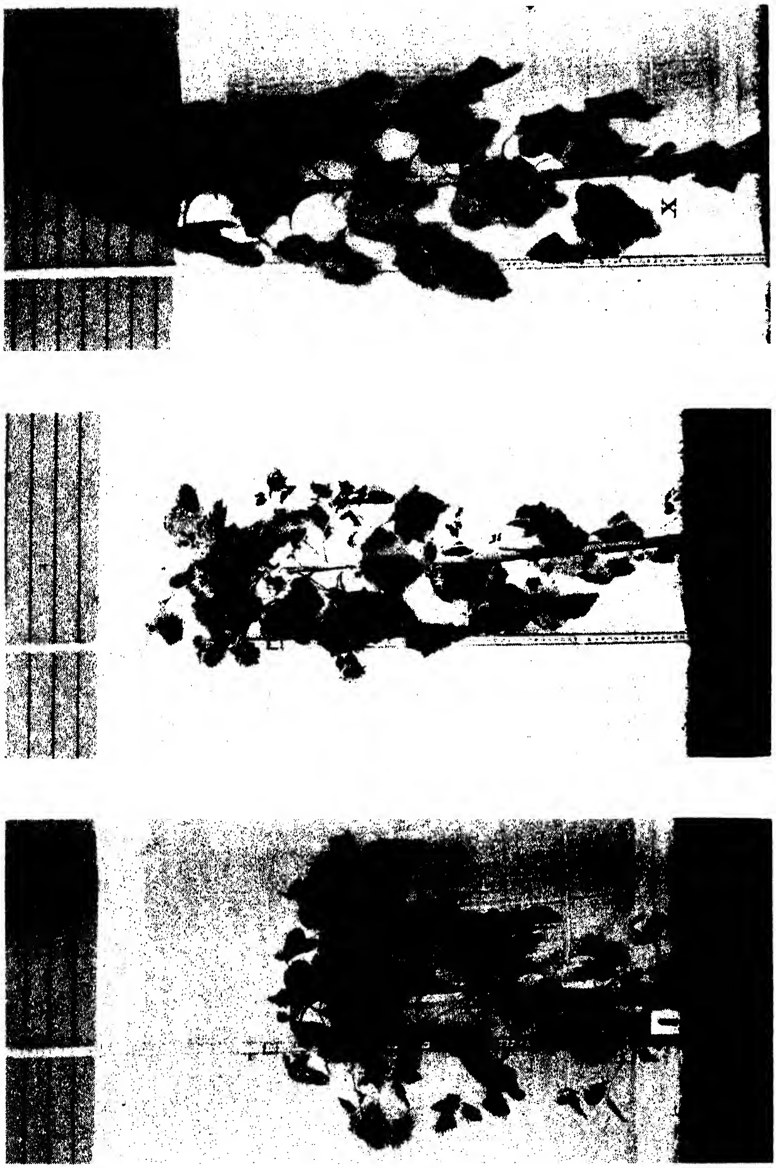
[4] The writer is indebted to A. E. Seamans, Assistant in Dry Land Agriculture, Huntley Experiment Farm, for his helpful interest in these studies.



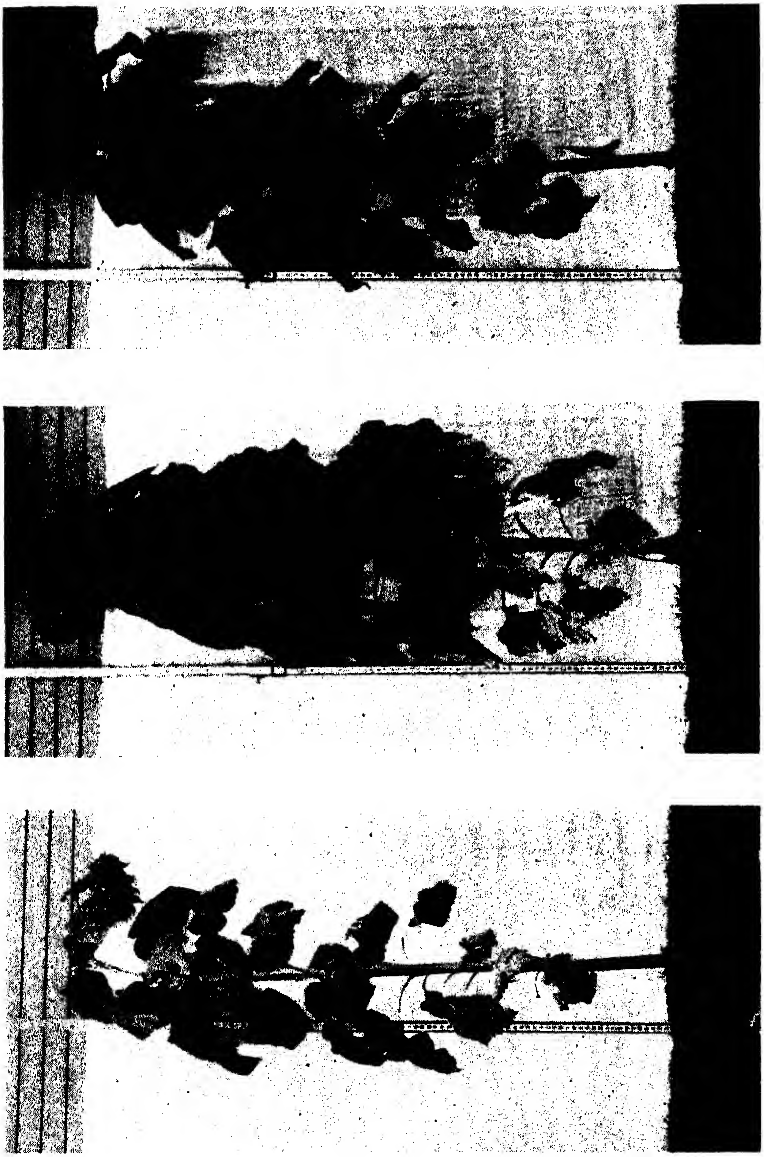
C

B

A



A B C



A B C

Type No. 1 — (6 per cent) Wild in appearance; branched, bearing heads on both primary and secondary branches; low growing and somewhat spreading; leaves mostly small, except on main stalks; stalk slender; plant light to yellowish; fully matured October 23; seeds generally small, striped to dark gray in color; (Plate II-A.)

Type No. 2 — (1 per cent) Single stalk, upright, about 6 feet tall; very broad leaves with relatively smooth margins; head of medium size with sharp crook in stem near base of head, giving "gooseneck" appearance; dark green; early maturity; seeds black with few white stripes.

Type No. 3 — (9 per cent) Very distinct type and relatively early; closely resembles No. 2, except leaves are a little smaller, sharply serated and apex more acute; about six feet tall; leaves appear to be almost in whirls on lower part of stalk; mature October 23; seed color variable (a) black with occasionally a white stripe and (b) seeds white with fine black stripes; very early, but not valuable for silage. (Plate I-A.)

Type No. 4 — (28 per cent) Tall, single stalk; unbranched; late; leaves roundly broad and deeply serated; stalk fairly thick; color variable but mostly dark green; apparently two strains; (a) matured October 23, and (b) matured November 11. (Plate III-A.)

Type No. 5 — (10 per cent) Very similar to No. 4, except for small axilary branches; seeds dark; immature November 11.

Type No. 6 — (8 per cent) Similar to No. 5, but plant is bushier and branches longer; fully matured October 23; seeds variable in color, light and dark in different heads of same plant. (Plate II-B.)

Type No. 7 — (25 per cent) Resembles No. 3, except that stalk is inclined to droop in "sickle" shape. The stem seems to taper off from about center toward head, giving appearance of long slender neck. Leaves sparse on lower part of stalk — distinct from No. 3 in this respect. Fully matured by October 23; seeds variable in both color and shape — dark to striped, and short to long; early, but foliage too sparse for high yield of silage. (Plate I-B.)

Type No. 8 — (11 per cent) Resembles No. 4, except at top. Leaves more numerous than on No. 4; shorter internodes, giving "pine top" appearance to plant; only few mature seeds found on November 11; ideal for heavy yields, but too tall for ease in harvesting. (Plate III-B.)

Type No. 9 — (1 per cent) Closely approaches No. 7, except that leaves are more numerous and much broader; plant low-growing, single stalk; stalky, with approach to "sickle" neck; no seed matured. (Plate I-C.)

Type No. 10 — (1 per cent) Tall, approaching No. 4 in height and general appearance, but has head and leaf characters of No. 3, and tapering at top of stalk similar to No. 7; no seed matured. (Plate III-C.)

Eight of the types described at Huntley were easily distinguished among the irrigated plants at Bozeman; but at the latter place No. 2 and No. 5 were not represented, whereas X, an eleventh type, was discovered. This type is extremely tall and late; it was not yet in full bloom when killed by frost.

Viable seed was secured of all the earlier types except No. 2, and will be used in connection with a continuation of these studies.

II — EFFECT OF BAGGING SUNFLOWER HEADS.

Uncertainty as to whether sunflowers are normally self-fertilized led the writer to bag a number of heads during the season of 1920 and observe their behavior. The effect of bagging on fertilization was so pronounced as to be of special interest.

The first effect to be noted was the disturbance of the normal flowering habit. Ordinarily, the flowers on the sunflower head

open in regular sequence from the periphery to the center of the head; and those in the outer circles are often withered by age before those in the center are even open. When bagged, however, all of the flowers on each head opened at about the same time. This was first observed quite by accident, after a storm had torn open one of the bags, but it was later confirmed by close examination of many different bagged heads, at Huntley as well as at Bozeman.

Another surprising result of bagging was that although the heads, and even the seeds, appeared to develop normally, practically all of the seeds were infertile. On some heads no fertile seeds could be found, whereas on others there were a few. In almost every instance, the head, in outward appearance at least, was as sound and fully developed as the unbagged heads, and every seed shell was of full size and typical color; yet there was absolutely no development of the kernel within the shell. In all cases the bags, containing an abundance of pollen, were agitated considerably by the wind — in a few instances by hand — but this made no apparent difference in the degree of fertilization which took place.

In this connection another interesting observation was made in the case of a plant bearing several heads, one of which was bagged. Every unbagged head matured normally developed seeds, whereas all the seeds of the bagged head were infertile. It is significant to note that at one time, on a single unbagged head, as many as ten insects, mostly bees, were counted.

These observations which afford convincing evidence of self-sterility in sunflowers are suggestive of the difficulties to be encountered in attempting to secure improved strains of this crop. That something more than the mere selection of heads will be necessary, is made plain by the fact that in 1920 head-rows planted from heads selected in 1919 displayed varying degrees of uniformity. In one head-row there was quite as much variation in type as was found in the plantings discussed in the first part of this article.

HERITABLE VARIATIONS IN MAIZE.[1]

C. B. Hutchison [2]

During the last ten or twelve years genetic researches have identified and determined the mode of inheritance of more than ninety distinct and heritable characters in maize. At the present time more than sixty hereditary factors in this plant are known and their genetic inter-relations fairly well understood. These factors are concerned with the development of characters which find expression in various parts of the plant and at different stages in its ontogeny. Thus sixteen are concerned primarily in the development of the seed, of which nine affect aleurone color, five endosperm texture, and two endosperm color. Seventeen are concerned primarily with chlorophyll development. Of these, four are responsible for characters that are visible in the seedling stage only, nine for those that show only in fairly advanced stages of maturity, while four others may be identified in both seedling and mature stages. Two others, in connection with various combinations of two of the aleurone factors, are responsible for no less than thirteen types of plant as respects mature plant colors. Another is concerned with silk color and still another forms a series of allelomorphs for pericarp and cob color. Ten are concerned with height, seven with various morphological characters affecting the leaves, ten with various ear characters, and eight with tassel characters.[3]

Most, if not all, of these variations in maize have been found apparently by chance, at least no systematic search had been made for them. Many of them have been found in the classes for freaks at various corn shows, some have been found by chance in fields, others have appeared in cultures of different investigators, while still others have been found in seed obtained from Indian reservations in the United States or imported for various purposes from foreign countries.

The fact that so large a number of variations in maize had been found apparently with little effort led the writer to think that such

[1] Paper No. 89, Department of Plant Breeding, Cornell University, Ithaca, New York. Received for publication, March 11, 1921.

[2] Professor of Plant Breeding.

[3] Some of these heritable characters in maize have been described recently in the Journal of Heredity. Descriptions of others are to appear in the same journal in the near future.

variations were perhaps much more common than is generally supposed and that a careful search for them even among the old and well established varieties would be rewarded. Accordingly in the spring of 1920 small samples of seeds of maize were collected from several seed companies and from a number of the northern experiment stations. No attempt was made to include all of the varieties grown in the northern states nor all varieties listed by the different seed companies from whom samples were obtained. Only those which gave promise of maturing in the latitude of Ithaca were sought. In some cases several samples of the same variety, particularly in sweet and pop corns, were obtained from different sources. In all approximately 650 different samples were collected.

Since the maize plant is ordinarily cross pollinated any commercial variety even after years of more or less careful selection consists of a hybrid and mechanical mixture of different strains. Recessive variations, though too weak to survive when homozygous, nevertheless may be carried along in a heterozygous condition and appear occasionally in an ordinary field of corn. When a plant which is heterozygous for such a character is selfed the variation appears in the immediate progeny in numbers approximating twenty-five percent if the character depends upon a single hereditary gene. It was, therefore, expected that by selfing a number of plants from each of the different lots of seed collected some of the ears produced would show such heritable variations as were present in a heterozygous condition in the original seed. From fifteen to thirty seeds of each sample were planted with the intention of selfing at least five plants of each lot. A severe drought immediately after planting resulted in a poor stand in some cases which, together with the necessity of caring for other cultures during the pollinating season, prevented the successful completion of the original plan. However, 2110 self pollinated ears representing 468 of the 650 lots of seed were obtained.

In genetic studies with maize, seed and seedling characters are especially desirable since individuals possessing such characters may be grown in large numbers in hybridization experiments with the minimum expense of time, labor and space. Apparently no unknown seed characters have appeared among these self pollinated ears, although this point cannot be determined definitely, of course, until certain genetic tests have been made. Defective seeds (2)[4], however, were rather common, appearing on 67 of these self pollinated ears.

[4] Reference by number is to "Literature Cited," p. 78.

During the present winter seedling tests have been made in the greenhouse of 1872 of these selfed ears, and a surprisingly large number of seedling variations found. Approximately fifty kernels from each ear were planted and the seedlings examined when they were about three weeks old.[5]

A summary of the observations made on the 1872 families from selfed ears shows that 681, or 36.4 percent, contained seedling variations of some kind. In most of these families a single variation was involved but in others two or even three were sometimes found. Of the 1872 families, 136 or 7.3 percent, contained morphological variations of various kinds, such as dwarfs, spearlike seedlings most of which are apparently completely enclosed within the coleoptile and soon perish, and various forms of twisted and cut stems or other fasciations. In most cases these morpholoigcal variations appeared in numbers approximating twenty-five percent and probably are simple recessives. Dwarfs of various kinds were most numerous, occurring in 23 different families, most of which were unrelated.

By far the most numerous seedling variations were chlorophyll deficiencies. These included white seedlings and white and yellow virescents found in 201 families, pale greens in 107 families, yellow and white striped or streaked plants in 58 families, and a miscellaneous group of chlorophyll characters in 164 families. In addition 45 families contained plants with a distinct waxy or glossy appearance of the leaves, in 44 of which about 25 percent of the plants were glossy, while in another family all of the plants showed this characteristic.

It is proposed to examine the progeny of each of these 1872 selfed ears for mature plant and ear characters by making a second planting in the field. As many variations of mature plant characters as of the seedlings are hardly to be expected, since such abnormalities are much more apt to be eliminated particularly from the older and well established varieties thru the usual process of seed selection. However, it seems probable that some variations will be found and doubtless in sufficient numbers to make a search for them worth while.

The number of variations so far found in this survey, as well as their frequency, is surprisingly large. Particularly is this true when it is recalled that only relatively few plants in each lot of seed were selfed. The largest number of plants selfed in any lot was fifteen and from each of only 144 lots were four or more selfed ears obtained.

[5] Most of the pollinating as well as the detailed work involved in making these seedling tests was done by Mr. Fred H. Dennis to whom the writer is indebted.

factors it would be more vigorous and hence yield better than originally. Lindstrom (4) questions whether the latter can be done. There is reason to believe, as he points out, that the genes for these abnormalities are scattered well thruout the chromosome complex. The same is doubtless true in respect to those elusive factors for growth, whatever they may be, upon which size and yield may depend. Therefore, he reasons that when one isolates and eliminates these inferior types by inbreeding one also eliminates some of the better factors for growth that are correlated with the unfavorable ones in inheritance. This, of course, would be true if these unfavorable factors were usually or always closely or completely linked with the better growth factors. It is difficult, however, to see why they should be linked more often with good growth factors than with poor ones and why, on the average, as many poor growth factors as good ones should not be eliminated along with the recessive allelomorphs of these abnormal or inferior characters by selective inbreeding. Furthermore, while some gametes would contain probably all of the other growth factors in a particular chromosome in which the gene for some abnormality is located, others thru the process of crossing over would contain quite different factorial complexes. Such an interchange between homologous chromosomes should result, sometimes at least, in the elimination of an inferior character without disturbing greatly the remaining factorial complex. The matter of finding such cases would seem to depend upon the number of inbred strains one could produce and the number of combinations between different inbred strains one could test. While one could hardly expect to eliminate all of the inferior growth factors and combine all of the superior ones of even two varieties thru inbreeding and subsequent crossing yet it should be possible by combining different lines from different varieties in double or even quadruple hybrids on a fairly large scale to find certain combinations of factors that would give better growth than any of the original varieties and which would remain fairly constant in subsequent generations.

LITERATURE CITED.

1. JONES, D. F. Dominance of linked factors as a means of accounting for heterosis. *In* Genetics 2: 466–479 1917.
2. ——————— Heritable characters of maize. IV. A lethal factor — defective seeds. *In* Jour. Hered. 11: 161–167. 1921.
3. KIESSELBACH, T. A. and RATCLIFF, J. A. Freezing injury of seed corn. Neb. Agr. Exp. Sta. Res. Bul. 16: p. 1–96. 1920.
4. LINDSTROM, E. W. Chlorophyll factors of maize. *In* Jour. Hered. 11: 269–277. 1920.
5. MONTGOMERY, E. G. Experiments with corn. Neb. Agr. Exp. Sta. Bul. 112: p. 1–36. 1909.

THE FIELD PROBLEM IN THE SOILS COURSE.[1]

A. B. BEAUMONT.[2]

The list of exercises for a standard course in soils recommended by the Lexington conference on soil teaching, June 23–25, 1920, contains one assigned problem in soil management. Due to the interest recently manifested by many in the improvement of the courses in soils and to a number of inquiries which we have received regarding our method of conducting the field problem, it was thought worth while to present to the readers of the JOURNAL the manner in which the field problem in soil management is handled at the Massachusetts Agricultural College.

These field exercises, of which the ones listed below are a development, were first tried out on a comprehensive scale in the fall of 1919. We feel that while they are not by any means perfect and will doubtless undergo further change as our experience lengthens, they have been remarkably worth while and have come to be an essential part of the courses.

Our group of vocational agricultural students, who are at college for two years only, and of which we ordinarily have a class of 150 to 200, are given the following considerable verbal instructions. Sheet 1 is taken by the students to the operator of the farm to which they have been assigned, to serve as an introduction and to give official college approval of the project. Sheet 2 contains detailed directions for the student. Sheet 3 is also in possession of the student.

Sheet 1.

Massachusetts Agricultural College

Agronomy S–I.

Field Problem in Soil Management.

The students of the Massachusetts Agricultural College, who are enrolled in the two-year practical course as well as the disabled service men assigned to the college by the Federal Board are required, as part of their work in the study of soils and fertilizers, to become familiar with some particular farm and its problems of soil management.

The work will include an outline map of the farm and a study of the following problems:

[1] Contribution from the Department of Agronomy, Massachusetts Agricultural College, Amherst, Mass. Received for publication May 23, 1921.

[2] Professor of Agronomy.

1. Moisture control; drainage, etc.
2. Methods of tillage.
3. The organic matter or humus of the soil.
4. Requirements of the soil for lime.
5. Use of manure and fertilizers.

The undersigned students have been assigned to a certain area. It is hoped that farm owners may be willing to permit the students to go over their farm for the purpose of this work.

Sheet 2

Massachusetts Agricultural College

Agronomy S-I

Field Problem in Soil Management.

Detailed Directions for Procedure

I. Draw to scale of not less than 500 feet per inch a map of farm, showing boundaries of fields, location of buildings and areas of different soil types. Color as follows: green = water, black = poorly drained, blue = clay, brown = sandy loams, yellow = infertile sand or gravel.

Sample carefully each soil type to a depth of 7 inches, and also subsoil to a depth of 20 inches. Bring samples into laboratory for mechanical analysis and acidity test.

II. The report must cover:

1. Moisture conditions.
   - How much land is now too wet to plow?
   - How much might be tile-drained?
   - Indicate on map possible location for mains and outlets.
   - How much is likely to be drouthy as indicated by subsoil and vegetation?
   - Describe topography; give amount and direction of slope.
   - Is land stony?
2. Tillage.
   - How much land plowed for this season's crops?
   - How much fall and spring depth?
   - How much sod and stubble?
   - Type and make of plow used.
   - Type of coulter used.
   - Types of harrow used.
3. Organic Matter.
   - Sod plowed under? How many acres?
   - Cover crops and green manure? How many acres?
   - Acres newly seeded. Time of seeding. Seed mixture.
   - Acres in hay last year.
   - Stock kept. Hay sold. Hay bought.
   - Manure applied where? Rate per acre.
4. Liming.
   - Fields needing lime as shown by vegetation. Results of acidity tests.
   - Has lime been applied recently and when?
5. Commercial Fertilizers.
   - Acreage of crops to be planted for 1921.
   - Manure used on each?
   - Amount per acre.
   - Method of application.
   - Brand name.
   - Analysis.
   - Cost?
6. Summary of methods of soil management, rotation and fertilization. Would the student make any changes if the management were in his hands? If so, state reasons.

Students will be assigned to this work in pairs. Map and report must be signed by each student.

Sheet 3.

Massachusetts Agricultural College.

Field Problem in Soil Management.

Directions for Sampling Soils.

1. (a) An auger 1½ inches or less in diameter may be used. (b) A spade or trowel may be used. A hole with one perpendicular side should be made and a thin slice taken from the side with any convenient instrument. Only one-fourth or one-half of this need be saved.

2. Take the samples from the plow depth. If in doubt take them from the first 7 inches of soil. Only a small amount of soil need be taken at each place.

3. (a) From fields whose soil appears to be uniform take samples according to one of the methods described above. From 6 to 10 samples should be taken at rather regular intervals, care being taken to avoid unusual situations, such as where brush has been burned, ash heaps or manure piles have stood, paths, etc. After all the individual samples are taken by one of the above methods, those for one soil type only should be thoroughly mixed in a clean pan, large sticks, stones, roots, etc., removed, and about a pint (which should represent one-third or one-fourth the mixture) removed for examination. This is a composite sample. (b) If the field contains considerable areas of soils of marked apparent differences (e. g. clay loam, sandy loam, muck) sample each type of soil as described under (a).

4. The composite sample prepared for testing should be labeled with the owner's name and the name or description of the fields from which taken. It is very important to avoid loss or confusion of labels, and it is advised that in addition to the label on the outside a label written in lead pencil on strong white paper be placed in the package of soil.

The character of the work turned in of course varies considerably in quality. Some of the students find considerable interest in the work and put in time far in excess of that required for class credit, while others put in the minimum only.

The following extracts from some of the reports should prove interesting:

(Extract 1)

Report of the Svrvey of the F——— Farm made by H. R. and G. P.

"The farm is located on the road between ——————————— and ——————————— and comprises about ninety acres (not including the woodland) all of which is alluvial soil.

There are some ten to fifteen acres more of woods attached to the southwest end of this farm. We were unable to obtain any measurements of these woods as Mr. F——————— was too busy to show us around and there are no land marks or other means of identifying his woods from those of the neighbors.

Moisture Control.— A good portion of the farm is well drained, but certain other parts notably pasture and meadow are in real need of some system of drainage. In the case of the pasture, Mr. F——————— did dig, some years previous, two short open ditches which emptied into the brook. These have, however, through lack of care and attention become almost completely filled so that they are now quite useless.

I could not see that it is the intention of the proprietor to install any further system of drainage, nor, in fact, to even dig out these old ditches. Apparently he has either not the time or money to place on this improvement."

(Extract 2)

"There were five acres of sod plowed under in the lower field and also tobacco stems which were strewn around before plowing under. There are no cover crops grown on the farm at all.

There were eight acres in hay last year but none was sold. This farm keeps, 5 work horses, 1 riding horse, 26 head of cows, 20 young head, 9 calves, 2 pigs. A few tons of hay were bought last winter.

Manure has been applied to lower field at the rate of 2½ cords per acre and on corn and tobacco land in the upper field 2½ cords per acre were also applied.

All of the pasture needs liming badly, indicated by vegetation and also six acres of land in the upper field where the soil is gravelly. Fertilizer was used on the lower field two weeks ago. There are 30 acres to be planted to 1921 crops made up of, 7 acres to soiling crops, 3 acres to corn, 10 acres to onions, 10 acres to tobacco. Muriate of potash was used as fertilizer this year. A hill-side plow was used this spring.

One suggestion I should make would be that the barns and sheds should have a better situation than they have at present. I should also drain the pasture out in the lower field. There is also a good chance to keep hens. Taken altogether I think the farm is handled on a good routine and management."

(Extract 3)

Liming.—"Fields need lime in spots. He used lime up to about three years ago but since he got a dose of potato scab he has not used it. All land shows slight acidity.

Commercial Fertilizers — He expects to plants eleven acres this year possibly more. There will be 15 tons of manure applied per acre with 600 pounds of fertilizer (Animal Brand, L. Fertilizer Company, analysis 3-8-4). On corn, potatoes, etc., the fertilizer is sowed in the hills to furrows by hand; other places a horse drawn sower is used. It costs about $57 per ton.

Mr. S—————— has got in my opinion a very nice farm. Were I running this farm I would first buy a couple of carloads of lime and use about two tons per acre, put more acreage into corn and clover. For instance he uses potato, corn and oat fertilizers while I would change this and use more clover and green manure, though there seems to be plenty of organic matter in the soil.

Nearly all his trees are headed high enough to use a tractor on where he plows and harrows the orchard once a year. I would buy a tractor and plow and harrow probably once a month. He uses a grass mulch, I would use a dust mulch."

(Extract 4)

"It seems there is no system of rotation or fertilizing. Should this land be in our hands we would recommend this land to be limed as it shows plenty of acid content by litmus tests. There should be drains put in as indicated by map diagram. There is a fine chance for an outlet as the brook or creek eventually ends in the Connecticut river. This land will eventually be used for poultry and fruit growing as this is Mr. M——————'s plans, so that is the real reason for no developments in the bringing up of soil structure."

This sort of field problem has not as yet been introduced into the introductory course for four-year students. It is intended to introduce a modification of the above problem next year.

To students, juniors and seniors of the four-year course, who elect our course in advanced soils, soil classification is stressed as shown by Sheet 4. On account of a much greater time allotted and a more extensive preparation, more exhaustive reports are expected from the advanced students than from the vocational students.

Sheet 4.

Massachusetts Agricultural College

Agronomy 75.

Directions for Field Work in Assigned Areas.

I. *General Survey*

The entire area must be surveyed and mapped (using map given). Indicate type areas on topographic map with hard pencil, letting certain numbers represent soil types. Finally the areas are to be colored using a uniform system which will be given later. A general report on the area assigned is to accompany the map. This report will include:

1. Location and boundary of area.
2. General physical features.
3. Description of soils and systems of soil management followed on them.
4. Discussion and suggestions, if any, for improvement.

The topographic map assigned must be mounted on stiff cardboard folder for field work.

Three weeks (from October 18th) will be allowed for completing this work. (Parts I and II)

II. *Detailed Survey*

In the area assigned select a farm of not less than twenty acres and, with the occupant's permission, make a detailed study of the farm from the standpoint of soil management. The final report will include:

1. A soil map of the farm on which are shown fields, brooks, buildings, etc., drawn to a scale not smaller than five hundred inches to inch. Give name of owner or occupant of the farm.
2. Detailed description of soil types on the farm and systems of soil management covering:
   a. Moisture control
   b. Methods of tillage
   c. Soil organic matter
   d. Liming
   e. Commercial fertilizers
   f. Cropping systems
3. Discussion and suggestions, if any, for improvement, with reasons.

Composite soil samples for the surface (0"–7") and subsurface (7"–20") of each type are to be brought to the laboratory for mechanical analyses, determination of water-retention capacity and lime requirement estimation.

Following are extracts from some of the reports on sheet 4:

(Extract 5)

1. Location and Boundary

"This area is situated in the northern part of the town of ——, Hampshire County, Mass., bordering on the Connecticut river. The southern boundary begins at the junction of the —————— Road with the —————— Road and extends along it to the river road. From here it extends northwest to the river then swings to the northeast meeting the —— Road where the brook crosses it. From here the line runs southeast crossing the ———— Road and gradually changing direction to southwest until it reaches the lower —————— Road. (See area marked in ink on the map.)

2. General Physiographic Features.

Beginning at the river there is a narrow strip of river-laid soil which is still subject to overflow. Moving east the area is cut practically north and south by a small creek. From the creek bed the ground rises some forty feet to a ridge or series of sand knolls. A branch extends southeast from the main ridge near the southern part of the area (see map) giving the knoll a forked appearance. From this point to the eastern boundary the land lies practically level. The

altitude varies from 100 to 160 feet above sea level. Drainage is good except for comparatively narrow strip of marsh along the creek bottom.

3. The soil of the river flood plain is Podunk fine sandy loam. The soil is dark brown in color over brownish gray subsoil. The subsoil is sandy. Soil is well suited to grass and heavy truck crops.

Practically all the remainder of the area is Hartford fine sandy loam. The soil is brown to light brown in color underlain by yellowish sand. The soil is of glacial lake deposit and has good drainage. Topography is level except for sand ridges which may be result of wind action. The soil seems well adapted to truck crops such as tobacco, onions, and grass and corn do well.

A modification of this type is found in the sandy knolls running thru the area which correspond very closely in texture to the subsoil of this series. The formation is undoubtedly the same.

4. The Podunk soil in this area was largely in timothy with several acres of onions and a few acres of asparagus. All of these crops are doing well and seemed adapted to the soil type. The Hartford soil on the flat is growing tobacco, onions, grass, corn, potatoes and asparagus. Some stock is kept on most of the farms but most of the farmers rely largely on commercial fertilizers and turning under green crops to keep up the humus content of the soil. In most cases the farms are well balanced and the methods modern. One or two instances were noticed where the farmer was sticking to the old fashioned rotation of hay, corn and potatoes and feeding cows of medium capacity. The cream is carried to the creamery and the milk fed to young stock. One said he had been farming there forty-five years and from all appearance, he had made little change in method during that time. He would make more money if he followed the example of some of his neighbors and raised a few cash crops such as tobacco or onions."

Detailed Survey of the Farm of G. C———.

"There are two types of soil found on this farm both of the Hartford series. The fine sandy loam soil is the only soil kept in cultivation as the sandy knolls are grown up to scrub oak, pine and bushes. I think the farmer is doing right in leaving these knolls as, if they were cultivated there would be danger of their injuring the good soil by erosion and wind. This farmer practises no definite rotation but makes a practice of following grass with corn or potatoes for a year or two and then reseeding to grass and clover. The timothy is usually left about three years. Mr. C——— also has a small patch of alfalfa started but raises nothing in the line of cash crops except a few potatoes.

About twenty head of cattle are kept on the farm, the corn and hay being mostly fed out. The cream is taken to Amherst Creamery and the milk to feed the young stock. The corn showed a good yield of good grain but it would need to, on land worth upwards of $300 an acre. I think Mr. C——— would do better to raise some cash crops such as tobacco and onions and reduce the amount of stock. He already has a tobacco shed on the square of ground bought at the south of his main strip of farm land. His neighbors are making a good success of these crops and his land is practically the same."

(Extract 6)

1. Location and Boundary.

"The area surveyed was oval shaped, approximately one mile long and one-half mile wide, and situated in the town of S———, Mass. To be exact it lies due north and south and stretches from the C———homestead northward till the sharp bend in the road is met a mile further. The street railway runs thru center of the area. It is bounded on the north by the Mohawk Brook; stretches eastward as far as fourth farm house located on road to L———; on the south boundary by the Long Plain Brook and on the eastern boundary by an imaginary line one-half a mile from opposite eastern boundary at greatest width.

2 General and Physiographic Features.

The topography of the area surveyed was very much varied. Practically parallel strips of increasing altitude eastwards, ran north and south. In fact it was one continuous slope from east to west with occasionally longitudinal sandy moraines

intercepting on west side of car track and before meadows were reached. The soil is universally sandy thus giving a loose structure to the soil and providing excellent soil surface drainage thruout. Vegetation was excellent, except on moraine tops where pine and birch trees grew abundantly. Long Plain Brook which passes thru southern end of survey had overflowed often, it seems, and the old brook bed filling up with accumulated gravel and stone, had spread until rocks of considerable size and gravel and stone had been deposited in large amounts upon the lower lands causing them to be practically useless under cultivation.

3. Descriptions of Soils and Systems of Soil Management.

In general the soil was the same over the entire area surveyed, that is, a surface soil of medium sandy loam, brown in color, and a medium brown sandy sub-soil. In specific areas this varied, as in the northeastern part we found a coarse sandy top and sub-surface soil predominant, with a surplus of loose stones on surface. On the top of the sandy mounds the sub-surface and surface soils were as one. The meadows were very moist soils varying from light brown sandy soil to a silt on top; and a brown medium sand to a clay beneath. Near the brook bed the auger was hard to turn often, due to surplus stones in sub-surface soils. Eight separate farms were found on this area and their chief crops were corn, tobacco, onions, and cover crops. To these the predominating Manchester sandy loam seems especially adapted. The usual system of cropping seemed to be alternate growing of onions and tobacco, or first a cover crop, then onions, then tobacco. The land owners took exceptionally good care of fertility of their soils under cultivation and replenished with corn stalks, tobacco stalks, farm manure and commercial fertilizer, the fertility of the soil. The lower meadows were mostly in grass except where overhead irrigation was put in and here onions were grown with tremendous profit and production per acre.

4. Discussion and Improvement Suggestions.

Little waste occurs in the area under survey and in general it is a great asset to the community of S———. Each individual farmer rotated his crops every one or two years and fertilized fully to avoid depletion. One possible and surely profitable improvement would be to drain some of the lower wet meadows and grow a more profitable crop on the fertile soil besides grass. Two mucky sections on west side of car track could also be drained and better utilized. Certainly the farm buildings could be repaired and improved to advantage."

(Extract 7)

Detailed Survey of a Thirty Acre Plot on the H——— Farm.

"The H——— farm is the most prosperous and best kept up farm in the entire 'section 6'. One field, a thirty acre plot, is the best land Mr. H——— owns. He runs a large dairy, selling his cream to local stores. On the farm is a large litter of pigs and many poultry. The stable manure is well supplied with wood shavings, of which he uses a great amount for bedding.

Systems of Cropping and Fertilizing.

Mr. H———'s entire stable manure supply is used on his own farm. He uses 3 tons of lime ashes per acre on this particular plot. He secures it from an agent at $8.00 a ton. Before the war he used potash. No chemicals are used. The area grows ensilage corn and hay this year. He employs no positive or set rotation of crops, but he usually grows a two year corn and two year hay rotation, using about half the field for each crop each year. What he calls 'hay' is a mixture composed mainly of red top with either clover or alfalfa. His rotation is never definite, however. His chief fertilizer is the manure of a fifty-head herd of cows. In spite of the lime ashes, the land is quite sour.

Detailed Description of Soil Types and Soil Management.

The Gloucester and the Essex series are prevalent on this thirty acre plot, the former being far more abundant. The northern section of the field is peculiar in the arrangement of the coarse sandy loam and the medium sandy loam due to small hummocks in the area, the latter type being on the more elevated ground.

In the north-western portion, small depressions like tiny sink holes have been formed in which water rises to the surface, even in dry times. These depressions are not being drained and quite an expense would have to be utilized in their complete drainage. The land on the mounds is much more covered with small stones than that in the slightly less elevated areas. Running parallel with a telephone line, which runs diagonally from the northwest, is a rather poorly built drainage system which is now 90% clogged up. A few laterals subtend this, but with slight success. Most of the field is naturally mucky. It is some years, about 8 or 10, that 6 inch drain has been laid. The southern part of the field is mostly of the Essex series. The lower land is mucky, very fine sandy black loam with a silty subsoil. The more elevated land is nearly the same, but dryer, with a medium sandy subsoil.

Suggestions for Improvements.

The land is *awfully* sour in spite of his attempts to neutralize it with lime ashes. If money permitted, the field would be greatly benefited by a new drainage system, because the present one is not working."

(Extract 8)

Soil Survey of the R. A. S——————Farm.

" The farm is located at the extremity of P—————— Lane on the right. The house and about six acres of land, most of which is set to orchard, lies between the two roads running south drom P—————— Lane. The rest of the farm is east of the farther road in a strip 222 feet wide and extending to a brook. The general slope of this land is to the east.

There were four types of soil found on the farm. There was a small strip of Gloucester silty loam in the north-west corner of the farm. Gloucester very fine sandy loam was found on the two slopes. Suffield silty loam was found in an area at the foot of the east slope and the Suffield clay loam occupied the flat land from there to the brook.

Recommendations.

Fields 1, 2, 5, 6 and 7 are being managed well. The land which has not already been limed should be and they should be fertilized each year.

Fields 3 and 4 are in poor condition but could be made very productive for hay land if limed, drained and fertilized a little. We suggest that he run a ditch down the north side of the fields next to the woods and clean out and enlarge the old ditch on the south side. These ditches would drain into the brook. With the slight slope and the sand content in the sub-soil, we thought this would be sufficient, but if not, cross tile drains could be resorted to.

Soil Acidity and Lime Requirement. Test Made on Three Soils.

No. 1 surface (fine sandy loam) No. 3 surface (silt loam) and No. 4 surface, clayey loam. (Note, by mechanical analysis of this type I determined that this soil was a *very fine* sandy loam.)

The three first qualitative tests showed strong acidity on No. 1, medium on Nos. 3 and 4. The subsoils of each were slightly acid.

The Truog test for acidity resulted as follows:

No. 1 surface soil — very strong acidity.
Lime requirement — 4 tons per acre.

No. 1 subsoil — slight — acidity.

No. 3 surface soil — Medium + acidity; Lime requirement — 2½ tons per acre.

No. 3 subsoil — slight + acidity.

No. 4 surface soil — strong acidity; Lime requirement, 4 tons per acre.

No. 4 subsoil — very slight acidity.

Mr. S—————————had limed part of a piece of the same soil type as No. 1. When I tested the surface (limed) with the Truog method the following result was obtained:

Very slight acidity. Lime requirement. No lime may be needed but if any about ½ ton per acre.

Organic matter and Maximum Retentive Capacity.

Duplicate tests were run on the soils. The results were as follows:

Organic Matter Estimation.	% organic matter.	
Surface of No. 1	a. 11.0% b. 9.8%	Av. 10.4%
Subsoil of No. 1	a. 4.0% b. 4.2%	Av. 4.1%
Surface of No. 3	a. 10.0% b. 9.8%	Av. 9.9%
Subsoil of No. 3	a. 5.4% b. 5.4%	Av. 5.4%
Surface of No. 4	a. 6.6% b. 6.4%	Av. 6.5%
Subsoil of No. 4	a. 3.0% b. 2.8%	Av. 2.9%

Maximum Retentive Capacity.

Soil	% Max. H_2O
Surface No. 1	38.6%
Subsoil No. 1	44.0%
Surface soil No. 3	67.5%
Subsoil No. 3	43.0%
Surface No. 4	38.5%
Subsoil No. 4	44.3%

For the Mechanical Analysis Experiment, I used the soil which I classified as clayey loam, No. 4; but the analysis of both subsoil and surface soil proved that the soil is a *very fine sandy* loam.

Mechanical Analysis of Soil No. 4. (Surface Soil) 10 grams sample of oven-dry soil used.

Separate	*Weight (grams)*		%
Fine gravel	.07		.7
Coarse sand	.30		3.0
Med. sand	.67		6.7
Fine sand	4.60		46.0
Very fine sand	1.55		15.5
Silt	2.11		21.1
Clay	.70	(by difference)	7.0
	10 grams		100.0

Or the surface soil contains

Sands.........71.9%
Silt...........21.1%
Clay...........7.0%

Subsoil

Separate	*Weight (grams)*	%
Fine gravel	.04	.4
Coarse sand	.24	2.4
Med. sand	.97	9.7
Fine sand	4.71	47.1
Very fine sand	.54	5.4
Silt	2.11	21.1
Clay	1.31	13.1

Recommendation: Same as given in report.

We feel that field work such as above reported is valuable to the student because it forces him to think in terms of soil science and soil management, because it brings him in contact with the actual farmer and his problems and because it shows the relation of soil knowledge to other phases of agriculture, particularly farm management.

THE CHARACTER OF 1919 CROP SPRING WHEAT DOCKAGE.[1]

C. H. Bailey.[2]

During the crop year 1919–1920 the Minnesota Experiment Station, in cooperation with the Minnesota State Grain Inspection Department, conducted an investigation of dockage in spring wheat. As one phase of this investigation the dockage removed from a large number of samples was separated into its several components, and the proportion of each was determined. Two series of samples were employed: (a) four 100 sample lots of spring wheat representing inspection samples drawn by the State Grain Inspection Department at Minneapolis over a period of about eight months, and (b) samples of spring wheat collected by representatives of the Experiment Station and the State Grain Inspection Department from country elevators in the principal wheat producing sections of the State.

Dockage was separated in the manner customary to the inspection and grading of spring wheat. The total dockage was then divided into three groups or classes of material as follows: (1) coarse fraction, after separation of wild oats; (2) wild oats; and (3) fine seeds and dirt. The first fraction consisted chiefly of tame oats, barley, straw nodes, rose hips and the like. The second group was, as indicated, made up entirely of wild oats, while the character of the third group is shown in Table 2.

Table 1 gives the average percentage of each of these three fractions, the total of the three fractions, and the percentage of dockage as determined by the State Grain Inspection Department. The difference between the latter and the total found in this laboratory is not great. It is, moreover, not far different from the average dockage found in all samples of spring wheat inspected by the State Grain Inspection Department during the 1919 crop season, which

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was 4.57 percent. Wild oats constituted quite uniformly about one-third of the total dockage in these samples.

TABLE 1.—*Average percentage of dockage in each of the 100 sample lots of spring wheat from the state grain inspection department.*

Dockage.	Lot 1.	Lot 2.	Lot 3.	Lot 4.	Average
Coarse dockage (except wild oats) per cent	0.72	0.47	0.27	0.28	0.43
Wild oats, percent	1.88	1.51	1.49	1.39	1.57
Fine seeds and dirt, percent	2.71	2.48	3.14	3.02	2.84
Total of the three fractions, per cent	5.31	4.46	4.90	4.69	4.84
Total dockage reported by Grain Inspection Department, per-cent	5.01	4.40	4.88	4.68	4.74

Barley was found to the extent of more than a trace (0.1 percent) in 45 of the 400 samples. The average quantity in these 45 samples was 1.02 percent, and calculated on the basis of the 400 samples the average in the whole was 0.11 percent, or a little more than a trace.

Tame oats were found in 29 of the 400 samples. The average in these 29 samples was 1.51 percent, and thus in the entire 400 samples the average was 0.11 percent. This is in addition to the average of 1.57 percent of wild oats.

Flax was found in 9 of the 400 samples. In four instances the quantity was fairly considerable, being 3.5, 5.0, 17.1, and 20.9 percent respectively. In the other five samples the average was 0.8 percent.

In addition to the separable impurities or dockage, the inseparable weed seeds were also determined. Corn cockle was present to the greatest extent, being found to the extent of more than a trace in 23 of the 400 samples. In these 23 samples the quantity found averaged 1.02 percent. Wild vetch, or wild peas as they are sometimes called, occurred in only 10 samples of the 400, and in these 10 samples averaged 0.52 percent. Kingheads, or the seed of giant ragweed, were found in only 6 of the 400 samples, and in these six samples averaged 0.84 percent.

The fine seed and dirt separated from each of the 100 sample lots were, after compositing, analyzed and the percentage of each of the seeds represented was determined. In addition to the weed seeds, this fraction contained appreciable quantities of small and broken wheat kernels, the average being 28.25 percent. It is impossible to completely separate such wheat either in using the sieves ordinarily employed in determining dockage or in commercially cleaning grain, especially when dealing with such shriveled, light-weight grain as constituted the bulk of the 1919 spring wheat crop. The fine seed and dirt fraction also included considerable chaff, stems, dust, etc., the average being 5.75 percent.

The principal seed components of this fraction were yellow foxtail, green foxtail, wild buckwheat, wild mustard and hare's ear mustard, these five seeds constituting 87.86 percent of the fine seeds and dirt *after* the wheat had been removed. The percentage of each of the components is shown in Table 2.

TABLE 2.—*Analysis of the fine seed separated from grain inspection department samples.*

Material.	Lot 1. Percent.	Lot 2. Percent.	Lot 3. Percent.	Lot 4. Percent.	Average: As found Percent.	Average: On wheat free basis Percent.
Small and cracked wheat kernels	30.00	31.00	18.50	33.50	28.25	0.00
Chaff, dust, stems, etc.	5.00	5.25	7.00	5.75	5.75	8.02
Yellow foxtail (Setaria glaucus)	18.50	21.25	24.00	21.00	21.19	29.52
Green foxtail (Setaria viridis)	36.00	28.00	34.00	23.75	30.44	42.43
Barnyard grass (Echinochloa crusgalli)	......	.50	1.25	1.25	.75	1.04
Wild mustard (Brassica arvensis)	2.50	3.50	3.75	3.75	3.37	4.70
Hare's ear mustard (Conringia orientalis)	1.50	4.00	4.00	3.00	3.12	4.35
Wild buckwheat (Polygonum convolvulus)	6.00	4.25	4.50	5.00	4.94	6.86
Ladies' thumb (Polygonum persicaria)	T	.25	.50	.50	.31	.43
Pennsylvania smartweed (Polygonum pennsylvanicum)	T	......	.75	.75	.37	.52
Pigweed (Amaranthus retroflexus)	T	.50	.50	.50	.37	.52
Lambs quarters (Chenopodium album); French weed (Theaspi arvense); Curled dock (Rumex crispus); Cow cockle (Saponaria vacarria)	0.50	1.50	1.25	1.25	1.12	1.56

T (trace) indicates less than 0.1 percent.

Recalculation of the foregoing data, shows that the 400 samples examined contained 4.03 percent of impurities of all description, including barley and tame oats. The last two items amounted, on the average, to 0.22 percent.

The 400 samples obtained from the State Grain Inspection Department represented the average of receipts from the entire spring wheat district commercially tributary to Minneapolis. In order to secure more definite information concerning dockage in Minnesota spring wheat, representatives of the two institutions were sent to

about 80 country shipping points in the principal wheat growing sections of the State, where they secured samples representative of the grain marketed at those points, For convenience in tabulating the results of tests of the samples thus secured, the territory covered was divided into three zones: (1) Minnesota River Valley, (2) Southern Red River Valley, and (3) Northern Red River Valley. Dockage in the samples from these zones was determined in the same manner as before, and Table 3 gives the average percentage of each fraction, as well as the average weight per bushel of the samples from each zone. It will be observed that the character of dockage is somewhat different in each of the three zones. Spring wheat from the Minnesota River Valley contained more wild oats and less fine seeds than that from the Red River Valley. The average quantity in all three zones was rather large, exceeding that found in the average samples from the State Grain Inspection Department. This suggests, but does not definitely establish that the foreign matter or dockage in Minnesota wheat is greater than that in wheats grown elsewhere in the spring wheat district.

TABLE 3.—*Average percentage of dockage, and weight per bushel of samples from each of the three zones in Minnesota.*

Class of Dockage.	Minnesota River Valley.	Southern Red River Valley.	Northern Red River Valley.
Coarse dockage (except wild oats), percent	0.23	0.10	1.07
Wild oats, percent	4.40	2.41	3.21
Fine seeds and dirt, percent	2.72	4.64	4.56
Total of the three fractions, percent	7.35	7.15	8.94
Weight per bushel, lbs	51.30	51.90	52.60

The fine seeds and dirt fraction from each sample was retained, those from each zone were combined and the components of each composite sample were separated. Table 4 gives the results of this mechanical analysis. As in the case of the samples from the State Grain Inspection Department, yellow foxtail, green foxtail, wild buckwheat, wild mustard, and hare's ear mustard comprised the major portion (85.94%) of the wheat-free material.

With respect to impurities which were not separated in the ordinary determination of dockage there were marked differences in the samples from the three zones. Thus, 45 of the 83 samples from the Minnesota River Valley contained wild vetch after the dockage was removed, the average content in these 45 samples being 0.74 percent, or an average of 0.40 percent in the entire lot of 83 samples. Only four of the cleaned samples contained corn cockle seed, the average in the four samples being 0.75 percent. In the samples

TABLE 4.— *Mechanical analysis of the fine seed separated from samples of wheat from the three wheat producing zones.*

Material.	Minnesota River Valley.	Northern Red River Valley.	Southern Red River Valley.	Average: As found	Average: On wheat-free basis.
	Percent.	Percent.	Percent.	Percent	Percent.
Small and cracked wheat kernels	23.5	9.5	24.5	19.17	0.00
Chaff, stems, dust, etc	5.5	....	5.0	3.50	4.33
Yellow foxtail	39.5	23.0	39.5	34.00	42.10
Green foxtail	24.0	32.0	18.0	24.67	30.51
Barnyard grass	.8	2.0	1.0	1.27	1.57
Wild mustard	1.5	11.0	4.5	5.67	7.02
Hare's ear mustard	.5	7.3	2.0	3.27	4.05
Wild buckwheat	1.5	1.5	2.5	1.83	2.26
Ladies' thumb	1.0	1.5	0.5	1.00	1.24
Pennsylvania smartweed	.5	1.0	1.0	.83	1.03
Pigweed	.2	2.0	.3	.83	1.03
Lambs quarters	.2	4.2	.2	1.53	1.89
Mallow	....	1.5	....	.50	.62
Frenchweed	....	1.0	....	.33	.41
Evening primrose	....	1.0	....	.33	.41
Pepper-grass	.8	....	....	.27	.33

from the Northern Red River Valley about one-third contained kingheads after cleaning, with an average of 3.09 percent in these samples. The average percentage of kingheads in all the samples from this zone was 1.18 percent. Cockle, kingheads, and vetch were practically absent from the samples representing the Southern Red River Valley.

SUMMARY

Impurities are difficult of separation from shriveled spring wheat such as was represented in the crop of 1919. The fine dockage included considerable shrunken or shriveled wheat which could not be separated from the ordinary weed seeds by the usual processes of screening.

An average of 1.57 percent of wild oats was found in the 400 wheat samples obtained from the State Grain Inspection Department. The same samples contained an average of 2.84 percent of fine seeds and dirt. This consisted in large part of the seeds of green foxtail, yellow foxtail, wild mustard, hare's ear mustard, and wild buckwheat.

Wild oats constituted a larger percentage of the samples collected at 80 country points in Minnesota, averaging 3.71 percent in the 140 samples. The same weed seeds in the fine dockage predominated in these samples as in the 400 samples from the State Grain Inspection Department.

Inseparable seeds were found in varying percentages in the different sections of the State. Thus half of the samples collected in the Minnesota River Valley contained wild vetch seed, while about one-third of the samples from the Northern Red River Valley contained kingheads after cleaning. Neither kingheads nor wild vetch were found to an appreciable extent in the samples from the Southern Red River Valley.

A TREATMENT TO PRESERVE VALUABLE REPRESENTATIVE SAMPLES OF EAR CORN.[1]

C. S. DORCHESTER.[2]

One of the great difficulties encountered in Farm Crops teaching is to preserve representative specimens of grain against damage by the Angoumois grain moth and similar insect pests. It has been found very desirable to make rather extensive use of type samples or specimens for class study and exhibit purposes and anything that could be done to preserve such material would be of help in the crops teaching work. The Farm Crops Department of Iowa State College, after trying several methods, has found one which has proved very satisfactory for the preservation of samples of ear corn.

A transparent, rather glassy coating which protects against the angoumois grain moth, discourages mice, and helps to prevent the shelling of butt and tip kernels can be secured by dipping corn ears in pure white shellac. Not only does shellac protect and thereby greatly lengthen the life of a sample, but it actually improves the appearance of the corn.

From the exhibit standpoint the cost of coating with shellac is not excessive. The results of treating a number of ears with pure shellac indicate that the average cost per ear will be from 5 to 10 cents. The cost will vary considerably, the deep kernelled ears taking much more shellac than do those of the flinty, shallow kernelled type. In an effort to reduce the cost of treatment a solution of shellac and wood alcohol, half and half, was used. The coating obtained, while giving considerable protection, was found not to be heavy enough to keep out the grain moth.

In the fall of 1920 an effort was made by the college to obtain an extensive collection of corn varieties. Five ear samples of some 80

[1] Contribution from the Department of Farm Crops, Iowa State College. Received for publication November 12, 1921

[2] Assistant Professor, Farm Crops Department.

varieties representing nearly all sections of the United States were obtained. The expenditure of time and money, while not excessive, was entirely too large to be repeated in a year or two. It was thought that some protective coating or repellent might be applied to each ear. It was found that antimot, a preparation used by the United States Department of Agriculture, destroyed the luster and did not have a lasting effect. After a few preliminary tests, all of the 80 type samples were treated with a solution of shellac and wood alcohol. The alcohol was used in order that the expense of this experimental treatment might be reduced. When this exhibit was set up at the Iowa State Corn Show, a few people wondered what had been done to the corn, but the majority did not notice that it had been treated. The slight gloss imparted by the shellac enhanced the appearance of the corn.

To test the effectiveness of pure shellac, a few treated and untreated ears of Reid's Yellow Dent were stored under conditions most favorable to the Angoumois grain moth. Ear No. 1 was dipped in white shellac, Ear No. 2 in a half and half solution of shellac and wood alcohol, Ear No. 3 in antimot, and Ear No. 4 was not treated. A small cupboard containing a few old sorghum heads swarming with moths was used for the test. The corn was placed in this cupboard in the early part of the summer and left there for three months. At the end of that time an examination was made. The ear treated with pure shellac, while not entirely free from damage, was in much better condition than the other ears. Number 3 and number 4 which had the antimot treatment and no treatment, respectively, were completely riddled.

The corn ear which, so far as we know, was the first ear to be treated with shellac was treated in December 1920 and was placed on the office desk where it has been kept since that time. Untreated ears kept in the office have been so damaged by the grain moth and mice that the ears had to be removed. The shellaced ear has not been damaged in the least by the mice, but close examination in June 1921 revealed a few moth holes. These holes were marked and the ear, which in the original treatment only had been brushed with shellac, was then dipped. No further damage has been noted.

While the half and half solution used on the 80 type samples was quite satisfactory it has been deemed desirable, in view of the greater protection obtained, to use pure shellac in a second treatment of these samples.

The treatment with shellac promises to make it possible to preserve representative samples for permanent exhibit by eliminating

or greatly reducing the amount of damage from the Angoumois grain moth. Heretofore, the life of a corn sample, in spite of a more or less methodical fumigation, has been very short and the work of securing the different varieties has had to be repeated every two or three years. Samples treated with shellac and given reasonable care should keep much longer.

Besides being valuable as a method for protecting representative samples, the shellac treatment could well be used on mounted material, such as ears and ear sections, used in class and laboratory work. It is the plan of the Farm Crops Department to use shellac treated material in the making up of all new mounts.

AGRONOMIC AFFAIRS.

CHANGE IN PLACE OF PUBLICATION OF THE JOURNAL.

This JOURNAL has, ever since the beginning of its publication as a periodical, been printed and distributed by The New Era Printing Co., of Lancaster, Pa. For a number of reasons, it has now been deemed wise to transfer its publication to the J. B. Lyon Company, of Albany, N. Y. The new publishers assure the editor that they will be able to issue the JOURNAL promptly on the 15th of each month of publication, if the manuscripts are in their hands with reasonable promptness. If authors will cooperate with the editor by promptly returning corrected proofs, it seems to be possible now to assure subscribers that their numbers will in the future arrive promptly on the expected dates.

Correspondence concerning manuscripts for publication, changes in address, proofs, etc., should be addressed to the editor at the N. Y. State Agricultural Experiment Station, Geneva, N. Y.

CHANGES IN MEMBERSHIP.

The secretary has reported the following changes in the membership of the Society since his last annual report: new members, 34; resignations, 2; net gain in membership, 32. This makes the present membership of the Society, 718. In addition to this, there are 141 subscriptions to the JOURNAL by libraries, institutions, etc.

NOTES AND NEWS.

William E. Stokes has been appointed as Grass and Forage Crop Specialist at the Florida Agricultural Experiment Station.

A. E. McClymonds, formerly Extension Agronomist of the Colorado Agricultural College, has been appointed Superintendent of the substation farm at Aberdeen, Idaho.

According to a recent note in SCIENCE, Sir David Prain will soon retire from the directorship of the Royal Botanic Gardens at Kew, England. Many agronomists have been intensely interested in the researches at the Kew Gardens and will be glad to learn that the directorship is to be filled by Dr. A. W. Hill who, as assistant director since 1907, is amply qualified to continue the excellent work which is in progress.

Dr. H. H. Love, of the Department of Plant Breeding of Cornell University, during the month of January delivered lectures on the importance of the use of biometric methods in the interpretation of experimental results, at the Pennsylvania State College and at the New York Agricultural Experiment Station at Geneva.

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INTERTILLAGE OF CROPS AND FORMATION OF NITRATES IN SOIL.[1]

T. L. LYON[2]

Does stirring soil, as is done in the intertillage of corn, increase the formation of nitrates? Inasmuch as the land has already been plowed either in the spring or previous autumn there has been an opportunity for aeration, consequently it becomes a question whether the subsequent settling of the soil interferes with the nitrifying process. If intertillage does promote the formation of nitrates, it is presumably because of the aëration it affords. The published evidence that has been accumulated seems to indicate that stirring the soil during the growing season does not increase the formation of nitrates.

This conclusion has been arrived at by direct evidence and possibly by indirection. Evidence of the former character was furnished by Call and Sewell (1)[3] and (2) and was based on experiments in which certain field plats, kept bare of vegetation, were stirred with a corn cultivator at intervals thruout the growing season; while similar plats were scraped with a hoe to keep down weeds. These plats were sampled from time to time and determinations of nitrates were made. Such evidence should be conclusive for the soil and climatic conditions under which the experiments were performed.

What may mistakenly be considered evidence is derived from field experiments in which plats planted to Indian corn were subjected to treatments similar to those described above. No determinations of nitrates were made but the yields of corn were measured and, in the main, the two treatments produced about the same yields

[1] Contribution from Department of Agronomy, College of Agriculture, Cornell University, Ithaca, New York. Received for publication September 12, 1921

[2] Professor of Soil Technology.

[3] Reference by number is to "Literature cited", p. 108.

of grain. A considerable number of such experiments have been conducted and the earlier ones have been carefully reviewed by Cates and Cox (3), whose tabulations, when taken as a whole, indicate that cultivation is not beneficial to the corn crop except as it removes weeds, altho some of the experiments do show an increased yield of crop as the result of intertillage. Later experiments by Mosier and Gustafson (4) covering a period of eight years resulted in no larger crops of corn where cultivation was followed than where the soil was scraped. While none of these experiments are claimed by their authors or reviewers to mean that stirring the soil does not sometimes increase the formation of nitrates there is the probability that such a conclusion may be drawn, as an impression obtains in some quarters that increased formation of nitrates in a soil is always accompanied by increased crop growth. The subject is one that might well receive further investigation under conditions other than those that surrounded the experiments that have furnished the direct evidence cited above.

The reasons why further investigations are desirable may be briefly stated. The experiments by Call and Sewell were conducted in the Missouri river valley where nitrification is usually abundant owing to a large supply of nitrogen and a soil readily permeable by air because of its mechanical composition and its low moisture content. Under such conditions nitrate formation may be expected to proceed more rapidly in unstirred soil than it would in a heavier soil in a region of more copious and frequent rainfall and less active evaporation.

In any consideration of this subject it would seem to be desirable not to base conclusions on crop yields or on the nitrate content of soils on which crops are growing. It may be objected that crop yields are the ultimate consideration. But this does not explain the nitrate problem, which must be separated from the practical matter of crop yields. It should be remembered that crop production is not necessarily a measure of the quantity of available nitrogen in a soil.

EXPERIMENTS AT CORNELL AGRICULTURAL EXPERIMENT STATION.

Some experiments which were conducted at the Cornell Agricultural Experiment Station in 1911 and 1912 may add something to the available information on this subject; altho the effect of intertillage on nitrate formation was not a primary consideration in the investigation.

SOIL USED IN THE EXPERIMENTS.

The soil of the field in which the experiments were performed has been classified as Dunkirk silty clay loam. Its mechanical composition is as follows:

TABLE I.— *Mechanical composition of soil used in the experiments.*

Kind of soil.	First foot (per cent).
Fine gravel	0.40
Coarse sand	0.63
Medium sand	0.83
Fine sand	1.85
Very fine sand	12.90
Silt	60.83
Clay	22.63

The soil is a little too heavy for the best growth of corn; but following a dressing of farm manure, or a hay crop, rather good yields of corn may be obtained, sixty bushels to the acre being not uncommon.

The plats of land on which the experiments were conducted were one-hundredth acre in size, being 43.6 feet long and 10 feet wide with an intervening space of two feet. All plats were planted to corn, but a space 16 feet long and the full width of the plat was left unplanted midway between the ends. Each unplanted section received the same tillage or alternative treatment as did the planted portion of the plat. The three treatments to be discussed in this paper were (1) mulching with straw, (2) scraping off the weeds with a hoe, (3) cultivating thruout the entire growing season. The three treatments were on contiguous plats. Each treatment was repeated on four widely separated plats and the crop yields and moisture and nitrate contents of the soil here recorded are, in each case, averages of the four plats receiving the same treatment.

A diagram showing the distribution of the hills of corn on the plats, the space between the plats and the unplanted section of each plat is given below.

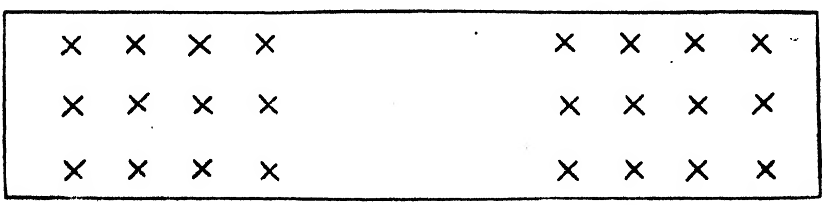


FIG. 1.— Diagram, showing planting plan of plats.

It will be noticed that there are three rows of hills on each plat. The variety of corn used was " Pride of the North " that had been grown on the same farm for many years. Five kernels were planted in each hill and later thinned to three stalks to a hill. Planting was done on May 20 in 1911 and May 22 in 1912. The straw mulch was spread on June 14 in 1911 and June 22 in 1912, at which time the corn plants were several inches high. No weeds grew on the mulched plats. The scraped plats were kept scrupuously free from vegetation and the soil was stirred as little as possible. The cultivated plats were stirred to a depth of about two to three inches with a cultivator. Cultivations were given on the following dates:

1911	1912
June 16	June 20
June 26	June 25
July 8	June 29
July 27	July 7
Aug. 21	July 20
Sept. 2	July 25
	Aug. 16

METHODS OF SAMPLING AND ANALYZING THE SOIL.

Samples of soil for moisture and nitrate determinations were taken with a one and one-half inch auger. Nine borings were made on each plat; which would be at the rate of one boring to each 48.5 square feet. Of these, six borings were made on the planted portions of the plat and three on the unplanted section. A composite was made of all the borings from the planted sections and another of the borings from the unplanted section.

Determinations of moisture were made by drying 100 grams of soil to constant weight at the temperature of boiling water. Nitrates were determined by extracting the soil with five parts of water, filtering thru a Pasteur-Chamberland filter, and using the phenol-disulphonic acid method for the remainder of the process.

In 1911, the soil was sampled to two depths, i.e., the surface eight inches and the underlying eight inches. Results indicated that it was the surface eight inches within which nitrates were largely produced and that the nitrate content of the lower depth corresponded to the upper, but in much smaller amounts. As it was expected to obtain only relative results, the second depth was omitted in 1912, but the surface borings were made to a depth of ten inches. In stating results of analysis made in 1911, the surface borings are used and the average of the first and second eight inch borings are also recorded.

NITRATES IN BARE SOIL.

The object in maintaining an unplanted section of each plat was to provide an opportunity to measure the effect of the several treatments on the nitrate and moisture content of the soil unsubjected to the influence of a crop. It will be seen in the diagrams that follow that, whereas there are marked differences in the nitrate content of the bare plats when cultivated and scraped, there are no consistent differences in the soil of the planted plats. For this reason the unplanted sections of the plats are used to measure the effect of the treatments on the formation of nitrates and on the conservation of moisture.

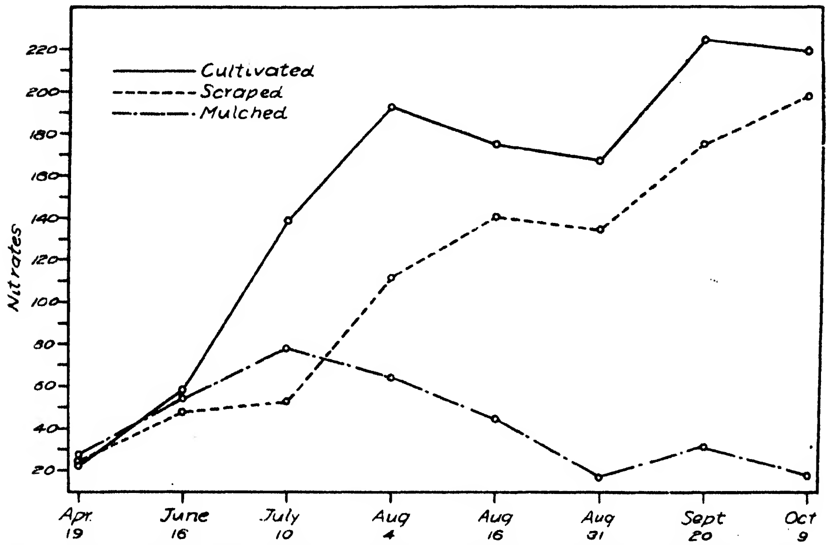


FIG. 2. Diagram showing nitrates in surface eight inches of unplanted soil in 1911.

In Figure 2[4] are graphed the nitrate determinations for each of the samples taken from the surface eight inches at various times during the summer of 1911. In Figure 3, the same data are recorded for the average of the first and second eight inches. In Figure 4, these data are shown for the surface ten inches in 1912.

The graphs referred to show in each case a marked difference in the effect of the three treatments on the nitrate content of the soil. Cultivation has perceptibly increased the formation of nitrates as compared with scraping. The nitrate content under the mulch is considerably less than under either of the other treatments. In 1911 this does not occur until after the mulch was applied; but in 1912 there was no strong recovery of the nitrifying process in the spring.

[4] The figures on which the graphs in this paper are based will be found in the appendix at the end of the paper.

MOISTURE IN SOIL.

The higher nitrate content of the cultivated plats would appear to be due to aëration of the soil rather than to any difference in the

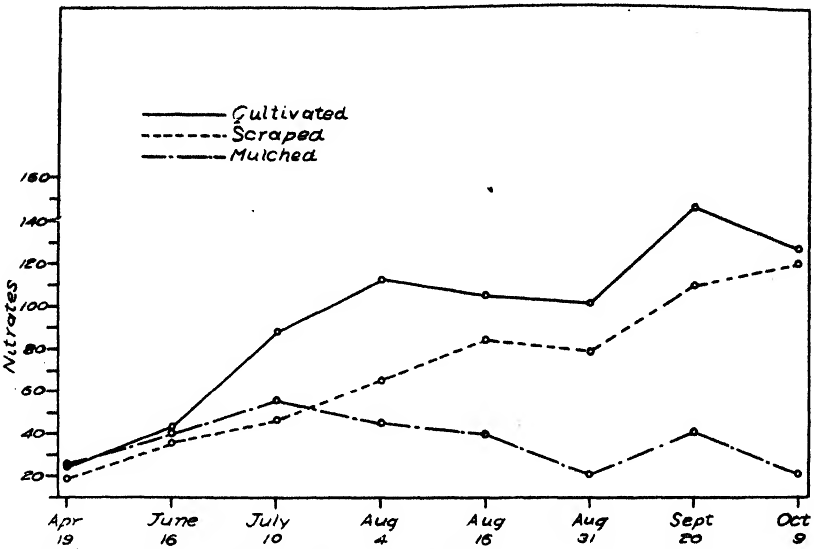


FIG. 3. Diagram showing nitrates in sixteen inches of unplanted soil in 1911.

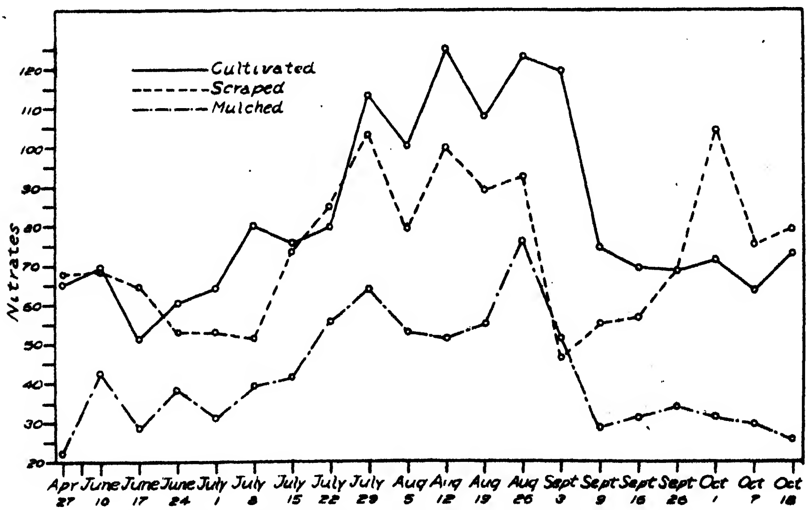


FIG. 4. Diagram showing nitrates in surface ten inches of unplanted soil in 1912.

moisture content. A graphical representation of the moisture content of the bare soil in these plats will be found in Figures 5 and 6. These show that the moisture runs higher in the mulched soil during

both years, but that there is practically no difference between the cultivated and the scraped plats during either year. The difference in nitrate content between the latter treatments can not therefore

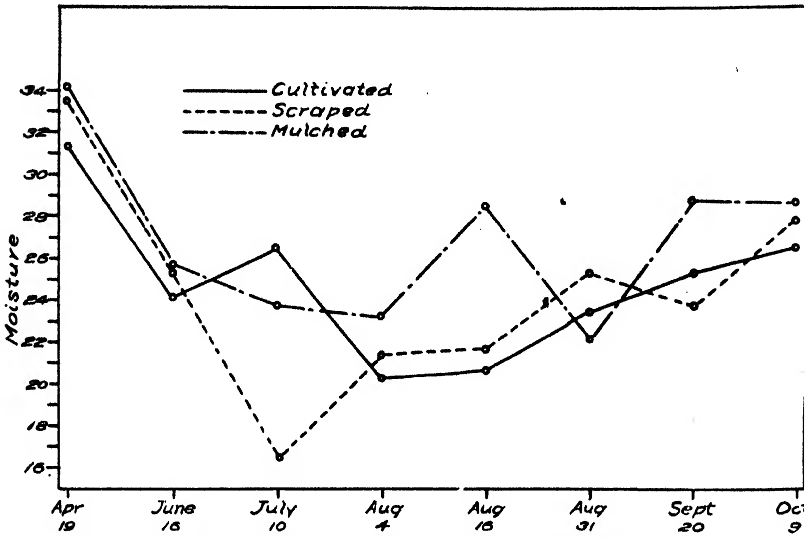


FIG. 5. Diagram showing moisture content of unplanted soil in 1911.

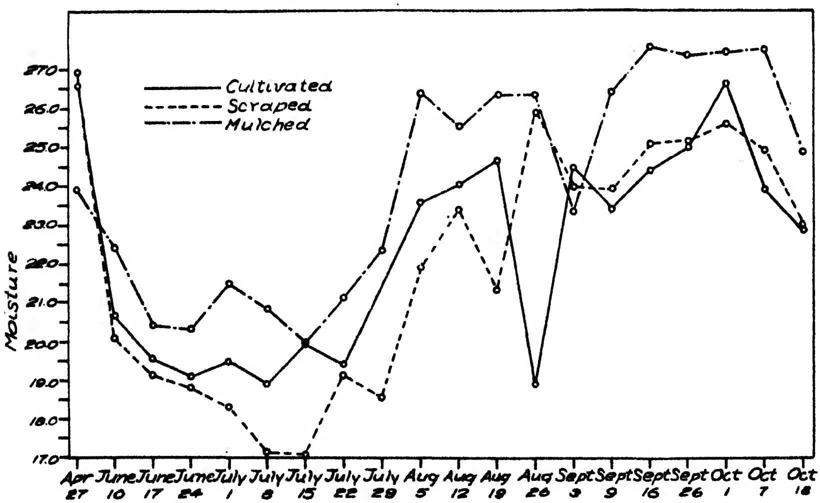


FIG. 6. Diagram showing moisture content of unplanted soil in 1912.

be attributed to the moisture content altho it is possible that the low nitrate content of the mulched plats may possibly be due in part at least to the high percentage of moisture they contained.

YIELDS OF CORN.

The corn was harvested at maturity and the weights recorded. In 1911 determinations of nitrogen in the crops were made. The results are stated in Table 1.

TABLE 1.— *Crop yields and total nitrogen.*

Plat numbers.	Soil treatment.	Yields on plats, pounds. 1911.	1912.	Nitrogen in crop. grams. 1911.
2203, 2211, 2403, 2411	Cultivated.....	159	126	541
2202, 2210, 2402, 2410	Scraped	118	116	392
2201, 2209, 2401, 2409	Mulched......	145	154	494

The larger yields on the cultivated than on the scraped plats may or may not have been due to the higher nitrate content. The plats were not supplied with abundance of other available plant nutrients and there is no assurance that nitrogen was the limiting factor. In fact it was apparently not the limiting factor on the mulched plats, which, while they were always lower in nitrates than the scraped plats, gave larger yields in both years than did the latter. This is a very good illustration of the fact that the productivity of a soil is not always proportional to its facility for nitrate production.

NITRATE CONTENT OF PLANTED SOIL.

In Figure 7 and 8 are graphed the nitrate contents of the planted sections of the scraped and cultivated plats during the summers of 1911 and 1912. Unlike the bare soil the planted soil shows no consistent difference in nitrate content between the scraped and cultivated plats. Any increase in formation of nitrates resulting from cultivation has been obliterated by the growth of corn. This shows that the nitrate content of a planted soil is not a reliable indication of the rate of the nitrifying process in that soil. The absorption of nitrogen by the plants and other influences that the growing plants exert on the transformations of nitrogen make this method unreliable for distinguishing between scraping and stirring in their effect on formation of nitrates in soil.

EFFECT OF AËRATION ON THE SOIL USED IN THE EXPERIMENT.

The fact must not be lost sight of that aëration increases nitrate formation in many, if not most, soils. It is possible that there are some soils so readily permeable to air that further aëration does not promote the nitrifying process. It is likely that a compact soil is more benefited by aëration than is a loose one. The soil on which these experiments were conducted responded to aëration

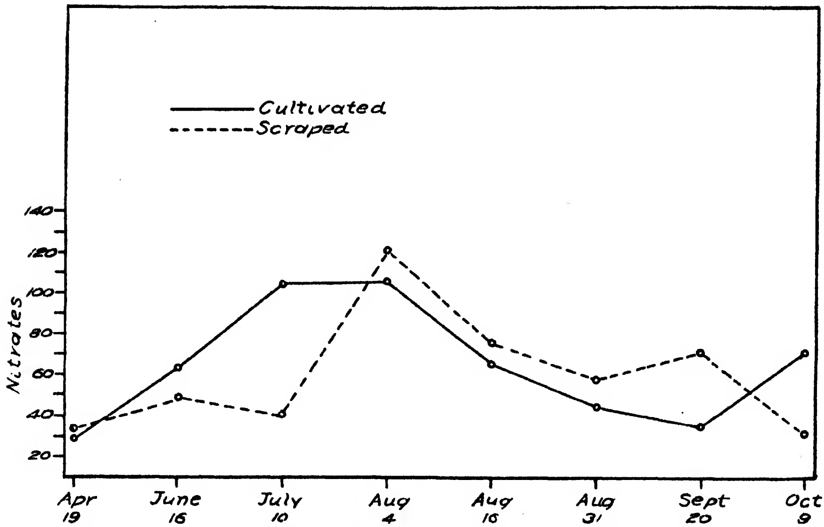


FIG. 7. Diagram showing nitrate content of cultivated and scraped, planted soils in 1911.

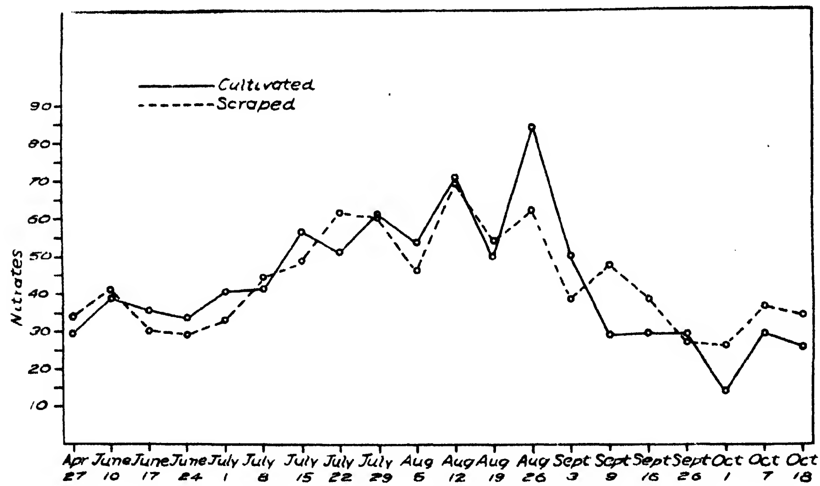


FIG. 8. Diagram showing nitrate content of cultivated and scraped, planted soils in 1912.

with increased nitrate formation. Moreover samples taken from more and less compact places in the field gave greater response from the more compact soil, as shown by the following experiments.

Samples were taken by driving into the soil an iron cylinder about eight inches in diameter and eight inches long. These samples

were transferred to a woven wire basket of about the same size, care being taken to effect the transfer without disturbing any more than was possible the cylinder of soil. The wire basket was then sealed on the sides and bottom with paraffin. Other baskets of the same size were filled with soil samples removed from the field to the same depth; but which were broken up so as to allow them to become aërated but not dried. This was done on Oct. 15. The soil stood in the greenhouse without being planted, but being maintained at a moisture content of 25 per cent of the dry weight of the soil. Nitrates were determined on November 7 and on January 5 following.

At the time that the soil samples were taken for the tests just described, estimations were made of the volume weight and porosity of the soil as it lay in the field. An iron cylinder eight inches in diameter and eight inches long was driven into the ground. The column of soil with the cylinder, was removed by digging the soil from around it and detaching the column from the lower soil by inserting a spade under the cylinder. The top and bottom of the soil column were then trimmed flush with the ends of the cylinders. The weight of the column of soil was thus obtained, and the percentage of moisture was determined in order to obtain the weight of dry soil. The interstitial space was calculated from these data.

The figures for pore space and for nitrates of both the more compact and less compact places in the field are given in table 2.

TABLE 2.—*Pore space in more and less compact soil and nitrates in the same soil aërated and unaërated.*

Soil.	Pore space per cent dry soil.	Nitrates. ppm. dry soil Nov. 7.	Jan. 5.
More compact soil, unaërated	37.5	4.2	trace
More compact soil, aërated	....	15.4	28.9
Less compact soil, unaërated	42.1	4.2	9.7
Less compact soil, aërated	....	17.6	26.0

Aëration evidently facilitated the formation of nitrates in both of these soils. The more compact soil when not aërated lost nitrates, while the less compact soil gained under the same conditions. When aërated, both soils made distinct increases in nitrate content.

YIELDS FOR FOUR YEARS ON SCRAPED AND CULTIVATED PLATS.

During two years prior to those mentioned above, tests were made of yields of corn on plats that were scraped and those that were

cultivated all season. The tests in 1907 were on a rather light sandy soil, those for 1908, 1911 and 1912, were on the soil already described. The relative yields for each year are shown in table 3.

TABLE 3.—*Relative yields of corn on cultivated and scraped plats when the former are taken as one hundred.*

Treatments.	Relative yields by years. 1907.	1908.	1911.	1912.
Cultivated	100	100	100	100
Scraped	96	89	74	92

In all cases the advantage in yield was with the cultivated plats. Whether this was due to an increased supply of nitrates or moisture or to some other cause does not appear. It illustrates, however, the result that has been obtained on a fairly heavy soil in a humid region having less evaporation than does the Mississippi valley.

SUMMARY.

Attention is called to the desirability of conducting experiments on fairly heavy soil of the North Eastern States to ascertain whether stirring with a cultivator under such conditions increases the formation of nitrates; investigations in the Middle West having indicated that stirring does not increase such action.

Experiments during two years on a silty clay loam soil at Ithaca, N. Y. to ascertain the effect of cultivating, scraping, and mulching with straw, respectively, on the nitrate content of unplanted soil and on the yields of corn are recorded.

Nitrates were highest during both years in the cultivated plats, next in the scraped, and lowest in the mulched. Determinations of moisture in these plats indicated that the higher nitrate content of the cultivated plats was not due to moisture; as that constituent was practically the same in the cultivated and scraped soil. The mulched plats had the highest moisture content.

Yields of corn were greater on the mulched than on the scraped plats; but this could not be attributed to the larger supply of nitrate nitrogen as the mulched plats also yielded more than the scraped altho the nitrates were much lower on the mulched plats. This is an illustration of the fact that the productivity of a soil is not always proportional to its facility for nitrate production.

The evidence here presented is in favor of the assumption that the nitrate content of the cultivated plats is higher than that of the scraped plats because of the aëration production by stirring with

the cultivator. Cylinders of soil taken from the field without disturbing the soil structure nitrified only slightly on standing at a moisture content and temperature favorable to the formation of nitrates, while similar soil that had been aërated gave a larger increase in nitrates. Under similar conditions a cylinder of soil from a more compact part of the field nitrified less than did one from a less compact section.

LITERATURE CITED.

1. CALL, L. E. and SEWELL, M. C. The soil mulch. *In* Jour. Am. Soc. Agron., v. 9:49–61. 1917.
2. ———, ———. The relation of weed growth to nitric nitrogen accumulation in the soil. *In* Jour. Am. Soc. Agron., v. 10:35–44. 1918.
3. CATES, J. S. and COX, H. R. The weed factor in the cultivation of corn U. S. Dept. Agr. Bur. Plant Indus., Bul. 257. 1912.
4. MOSIER, J. G. and GUSTAFSON, A. F. Soil moisture and tillage of corn. Ill. Agr. Expr. Sta., Bul. 181. 1915.

APPENDIX

TABLE 1.— *Moisture and nitrates in surface eight inches of uncropped soil during 1911.*

Dates of sampling	Moisture; per cent in dry soil			Nitrates (NO^3) ppm. in dry soil		
	Mulched.	Scraped.	Cultivated.	Mulched.	Scraped.	Cultivated.
Apr. 19....	34.1	33.6	31.4	27.2	23.3	21.8
June 16....	25.6	25.2	24.2	54.0	48.8	59.7
July 10....	23.8	16.6	26.6	78.8	52.9	138.7
Aug. 4....	23.4	21.4	20.3	64.2	112.0	192.2
Aug. 16....	28.5	21.8	20.8	46.5	141.5	174.5
Aug. 31....	22.2	25.3	23.6	13.7	135.2	168.5
Sept. 20....	28.8	23.8	25.3	31.6	176.5	224.0
Oct. 9....	28.7	27.9	26.6	18.2	198.7	209.7

TABLE 2.— *Moisture and nitrates, average in upper sixteen inches of uncropped soil during 1911.*

Dates of sampling.	Moisture; per cent in dry soil.			Nitrates (NO^3) ppm. in dry soil.		
	Mulched.	Scraped.	Cultivated.	Mulched.	Scraped.	Cultivated.
Apr. 19....	30.3	29.6	29.9	23.1	18.9	22.9
June 16....	23.5	23.6	22.3	39.9	34.6	42.8
July 10....	21.8	16.8	23.7	55.8	46.8	88.5
Aug. 4....	22.1	19.6	19.1	46.7	66.3	112.8
Aug. 16....	25.9	20.2	19.5	40.3	84.1	104.9
Aug. 31....	20.5	23.2	22.0	20.4	79.6	102.1
Sept. 20....	25.8	22.0	23.0	40.8	110.1	147.7
Oct. 9....	26.1	25.8	24.2	20.5	120.3	127.2

TABLE 3.—*Moisture and nitrates in surface ten inches of uncropped soil during 1912.*

Dates of sampling.	Moisture; per cent in dry soil. Mulched.	Scrapped.	Cultivated	Nitrates (NO^3) ppm. in dry soil. Mulched.	Scraped.	Cultivated.
Apr. 27....	23.9	26.9	26.6	22.6	67.7	64.9
June 10....	22.4	20.1	20.7	43.1	67.3	69.0
June 17....	20.4	19.2	19.6	28.5	64.8	52.3
June 24....	20.3	18.8	19.2	38.5	53.8	60.4
July 1....	21.5	18.3	19.5	32.2	53.4	64.2
July 8....	20.8	17.2	18.9	39.2	52.7	80.1
July 15....	20.0	17.1	19.9	42.4	74.1	75.9
July 22....	21.2	19.2	19.4	55.9	85.2	89.9
July 29....	22.3	18.6	21.5	64.3	103.1	113.4
Aug. 5....	26.4	21.9	23.6	53.4	79.2	100.7
Aug. 12....	25.5	23.4	24.1	51.9	99.8	125.3
Aug. 19....	26.3	21.3	24.7	55.0	89.0	107.5
Aug. 26....	26.3	25.9	18.9	76.3	92.9	123.2
Sept. 3....	23.3	24.0	24.5	52.4	47.0	119.1
Sept. 9....	26.4	23.9	23.4	28.6	55.2	74.4
Sept. 16....	27.6	25.1	24.4	24.8	57.1	69.1
Sept. 26....	26.8	25.2	25.0	33.9	68.9	68.4
Oct. 1....	26.9	25.6	26.7	32.2	104.3	72.2
Oct. 7....	27.0	24.4	23.9	29.7	70.4	64.1
Oct. 18....	24.8	22.9	22.8	36.0	79.5	72.9

TABLE 4.—*Nitrates in soil planted to corn during the years 1911 and 1912.*

1911

Dates of sampling.	Nitrates (NO^3) ppm in dry soil. Scraped.	Cultivated.
Apr. 19........	32.5	28.6
June 16........	49.7	63.1
July 10........	41.5	104.7
Aug. 4........	120.7	106.7
Aug. 16........	76.2	65.5
Aug. 31........	58.5	44.7
Sept. 20........	71.5	35.0
Oct. 9........	32.1	71.0

1912

Dates of sampling.	Nitrates (NO^3) ppm. in dry soil. Scraped.	Cultivated.
Apr. 27.......	34.1	29.7
June 10.......	42.0	38.9
June 17.......	30.4	35.6
June 24.......	29.3	34.4
July 1.......	33.3	41.1
July 8.......	44.8	41.3
July 15.......	48.2	57.3
July 22.......	62.6	52.2
July 29.......	60.0	62.1
Aug. 5.......	46.5	54.1
Aug. 12.......	69.6	71.0
Aug. 19.......	54.4	50.0
Aug. 26.......	62.8	83.8
Sept. 3.......	38.8	50.3
Sept. 9.......	47.5	28.9
Sept. 16.......	38.2	29.4
Sept. 26.......	26.9	29.3
Oct. 1.......	26.2	19.1
Oct. 7.......	36.5	29.7
Oct. 18.......	34.4	26.3

A SMALL GRAIN NURSERY THRESHER.[1]

O. F. Jensen[2] and M. E. Olson[3]

The thresher herein described was designed to avoid the labor of threshing by hand a large number of grain samples from yard square of similar areas used in the obtaining of plot yields from outlying fertility and crop production experiments. Three men using this machine have threshed and cleaned successfully 120 samples per hour, recording weights of both straw and grain. It is designed to be practically self cleaning so that it can be used for rod-rows, head rows, or any pure-line and plant breeding work in a small grain nursery. The thresher is not claimed to be entirely original in design; but it incorporates a number of desirable features observed in the operation of other small threshers. It can be built in its entirety by any good mechanic, the only important items to be purchased being a one-quarter horse power motor and a combined motor-forge blower with rheostat.

OPERATION.

The grain, fed through the over-shot cylinder, strikes a baffle board, and drops down into the drawer through a current of air which cleans the grain. A part of the grain and the chaff is carried onto the grain pan where a separation is effected by the air current and rapid vibration of the grain pan. All of the grain does not roll down into the drawer until the air current is shut off, which completes the threshing. The operator in feeding permits only the heads to go through the machine. Nevertheless, a few heavy pieces of straw will collect in the grain drawer. These are removed by pouring the grain through the screen, which has a slight vibratory movement.

ADJUSTMENTS.

Cylinder speed can be varied by means of different sized pulleys on the motor. The concaves can be raised from the cylinder by placing shims under the ends. The volume of the air current is controlled or shut off entirely by the rheostat. This adjustment, together with that of the angle of incline of the grain pan, makes the machine operate equally well for wheat, barley, or oats.

[1] Contribution from the Farm Crops and Soils Section, Iowa Agricultural Experiment Station, Ames, Iowa. Received for publication November 12, 1921.

[2] Formerly assistant in crop production.

[3] Formerly superintendent field experiments.

CONSTRUCTION.

The framework is constructed of dressed lumber, two by three inches, all joints in the sides mortised and tenoned, and the two sides joined by bolts through the five cross members. The cylinder is built of maple, mounted on a piece of three-quarter inch steel shafting, and then turned on a lathe to a diameter of six inches and a length of nine and one-quarter inches. The teeth are constructed from two and one-half inch No. 16 wood screws, with the heads cut off and tops forged to a rectangular cross section. They are screwed into the cylinder in diagonal rows rather than straight across the surface of the cylinder to insure smoother running. There are eight rows of seven teeth each. The cylinder runs in saw mandrel bearings bolted on the frame and the shafting has a five inch wood pulley grooved for round belting on one end, and a similar two inch pulley on the other end.

The concaves are made of maple, two by three inches, sixteen inches long, into which are screwed teeth similar to the cylinder teeth. Both sets of concaves are mortised at the ends to set firmly in place, and are bolted to the frame by bolts and wing nuts.

The baffle board, hinged directly back of the concaves, is constructed of one-half inch lumber, as is also the board below the feed table in front of the cylinder. The feed table is constructed of matched flooring.

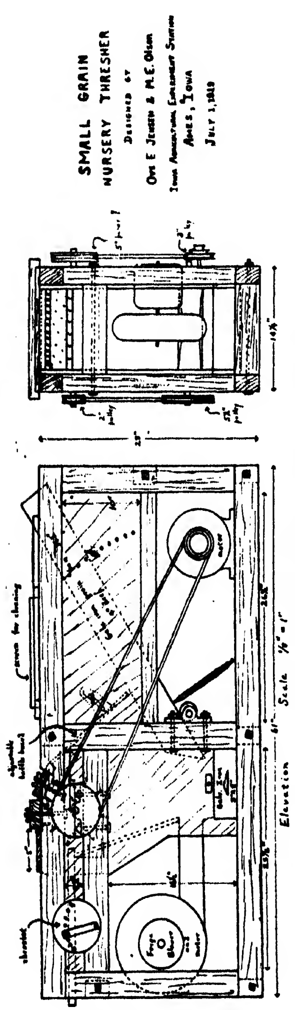
The forge blower and motor is mounted so as to direct a stream of air horizontally directly over the drawer which collects the grain, and through a sheet metal throat in which are baffle plates to insure an even distribution of air over the width of the grain pan. A rheostat mounted for convenience on the side of the machine controls the volume of air.

The grain pan, 36½ inches long and four inches deep, is made of sheet metal, and is supported ten inches from the upper end by an adjustable rod, on which it pivots. The lower end is held down on a cam by means of a spring. The cam is simply a two-inch circular maple pulley mounted eccentrically on three-quarter-inch shafting running in saw mandrel bearings. One end of the shafting has a five and one-half-inch wood grooved pulley, belted to the cylinder.

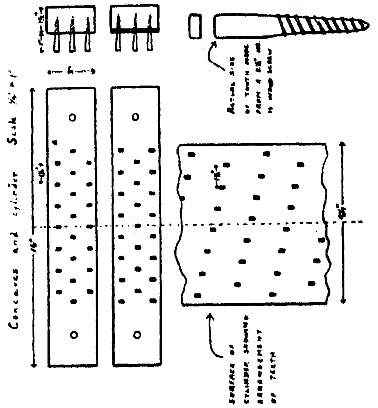
A frame on top of the machine holds a screen for cleaning the grain. One end of the frame is fastened by screws through holes in the top edge of the grain pan.

The one-quarter H. P. motor is mounted on the floor of the machine beneath the grain pan, and is connected to the cylinder with round belting. A motor having an R. P. M. of 1,750 with a

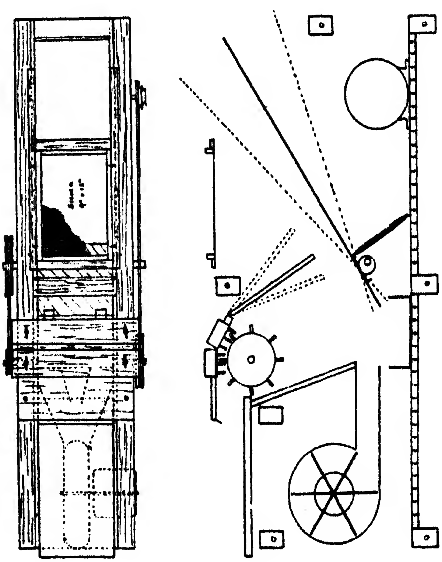
combination two, three and four-inch pulley gives cylinder speeds of approximately 580, 750, 1,000 R. P. M. and 200, 275, and 350 oscillations of the grain pan per minute.



Side and end views of nursery thresher.



Concaves and cylinder, showing arrangement of cylinder teeth.



Top view and section.

THE PHYSIOLOGICAL VALUE OF SMOOTH-AWNED BARLEYS.[1]

H. K. Hayes and A. N. Wilcox.[2]

INTRODUCTION.

The physiological importance of the awn in barley and wheat has been pointed out by various investigators. An appreciation of the facts is important to the plant breeder, for under many conditions it would seem that awned varieties may be expected to yield more than awnless.

The discomfort of handling awned varieties has led the farmer to plant awnless sorts when fairly desirable varieties of this type were available. This in turn has influenced many breeders to bend their energies toward the production of awnless varieties. Whether this practice is justifiable depends on the comparative value of awned and awnless strains.

The use of smooth-awned varieties of barley has been suggested by Harlan, of the Cereal Investigations office, Bureau of Plant Industry, and for several years cooperative breeding studies have been carried on at Minnesota and elsewhere with the hope of producing high-yielding, smooth-awned varieties of barley. The production of a new variety by crossing and subsequent selection is now based on Mendalian principles. Before introducing the new variety to the farmer, it is necessary to give it a thorough test. No smooth-awned strains are yet available for distribution but the experimental results so far obtained warrant the belief that smooth-awned varieties of high-yielding ability will eventually be produced. The evidence at hand is of two sorts: the comparative yield test of standard varieties and smooth-awned sorts, and a physiological comparison of several smooth-awned strains and certain standard varieties. Before presenting the experimental results, a brief review of earlier studies will be made.

STUDIES SHOWING THE PHYSIOLOGICAL IMPORTANCE OF THE AWN OF WHEAT AND BARLEY.

Zoebl and Mikosch (9)[3] compared the transpiration of awned spikes and of spikes with the awns removed for 2-rowed and 6-rowed

[1] Published with the approval of the Director as paper No. 289, Journal Series of the Minnesota Agricultural Experiment Station, St. Paul, Minn. Received for publication, November 25, 1921.

[2] Head of Section of Plant Breeding, Division of Agronomy and Farm Management and Assistant in Plant Breeding, respectively.

[3] Reference by number is to "Literature Cited" p. 118.

barleys and found that normal spikes gave off four to five times more water than spikes with the awns removed. Transpiration was the greatest at the time of carbohydrate formation in the seed Schmid (8) pointed out the relation between complete development of large seeds and the presence of the awn. He mentioned also the protective value of the awn.

Perlitius (7) made a careful study of the value of the awn for winter and spring wheat and for barley. Transpiration in spikes of awnless wheats was about the same as in spikes of awned wheat in which the awns had been removed. Removing the awns reduced transpiration by nearly 40 per cent in wheat and about 75 per cent in barley. The awn was shown to have an important relation on the volume and weight of the seed; the removal of the awn causing a reduction in average weight of seed of about 10 per cent.

More recently, Harlan and Anthony (4) have presented detailed results which prove very conclusively that the barley awn is an important physiological organ. They compared the daily development of kernels of clipped spikes (awns removed) with normal spikes. The found "about one week after flowering that the deposit of dry matter in the kernels of normal spikes begins to exceed that in the kernels in clipped spikes." The difference was increased progressively until maturity. They likewise found that at maturity the awns in normal spikes contained more than 30 per cent ash. When the awns were removed, a part of this ash was deposited in the rachis. This they believed to be the cause for the tendency of these spikes to break. These results may explain why hooded and awnless sorts shatter more than awned varieties.

Grantham (1,2), compared the yield of awnless and awned varieties of wheat. He found that the awned varieties averaged considerably higher in yield than the awnless and that awned varieties were less susceptible to plant diseases, such as scab. Studies carried on at the Minnesota station (6) have shown conclusively under the conditions of the experiment that the awn performed an important function. In F_3 to F_5 generation crosses of Marquis (awnless) with Preston (awned) the per cent plumpness of seed, the average length of seed per plant in millimeters, and the average yields per plant of awned and awnless plants were compared. The awned plants excelled in all three particulars.

Some of the families in F_3 and later generations were heterozygous for seed length while others were homozygous. In both the heterozygous and homozygous families the awned plants produced

an average seed length of about one millimeter greater than that of the awnless.

The use of smooth-awned varieties of barley, as has been suggested by Harlan (3), seems a logical means of overcoming the discomforts in handling awned barleys. Although smooth-awned varieties have been known for many years, Harlan has pointed out that no smooth-barley is widely grown commercially. This suggests a possible physiological limitation. The purpose of this note is to present some data which have a bearing on this question. The results are of two sorts: (1) comparative yield tests, and (2) comparative transpiration of smooth-awned and other varieties.

COMPARATIVE YIELDS TESTS.[4]

In an earlier publication (5), yield tests of smooth-awned barleys and of other standard Minnesota varieties were given. Several smooth-awned varieties were obtained which, in rod row tests, yielded as well as the standard strains of Manchuria. Two high-yielding smooth-awned strains were increased and have been tested for several years in field plots. In some years they have given high yields, but in several tests the yields have been low. This result is apparently due to the susceptibility of these new strains to *Helminthosporium sativum*. Accordingly, new crosses were made and new strains have been under rod row tests for the last two years. These new strains are resistant to *H. sativum*, as special attention was given to this character. As is shown by Table 1, they yield as well as the standard Manchuria variety.

TABLE 1.— *Comparative yields in replicated rod row tests of smooth-awned barleys and standard Manchuria. University Farm. 1920–21.*

Variety or cross.	N. S. N.	Yields in bushels per acre. 1920.	1921.	Average.
Manchuria	Minn. 184	48.4	31.2	39.8
Smooth Awn x Manchuria	II–20–7	41.7	31.1	36.4
Smooth Awn x Manchuria	II–20–8	45.8	33.2	39.5
Smooth Awn x Luth	II–20–9	55.5	33.2	44.4
Smooth Awn x Luth	II–20–10	58.2	32.4	45.3
Arequipa x Smooth Awn	II–20–14	44.5	35.4	40.0

COMPARATIVE TRANSPIRATION OF HEADS OF SMOOTH-AWNED AND OTHER BARLEYS.

Culms of the varieties to be used were collected in the field by cutting them as near the base as possible. They were placed in a

[4] Barley breeding is in cooperation with the Office of Cereal Investigations. The original crosses were made and the F_1 generations grown by Dr. Harlan of this office. Subsequent breeding studies have been carried on at the Minnesota station.

pail of boiled water and were then cut beneath the surface of the water at a point separated from the first cut by at least two nodes. Care was taken to use heads in which the seeds were at about the same stage (late milk) of development. After bringing this material to the laboratory, the stems were again cut under water, leaving about four inches of stem below each head. These stems were then inserted into 4-ounce, wide-mouth bottles. The bottles were previously prepared by filling with boiled water and by stretching across the mouth of each and fastening with a rubber band, a three-inch square piece of dental rubber dam which was punched with eleven fine holes, ten of which were for the barley stems and the other to carry a fine glass tube which was to serve for admitting air to take the place of the transpired water. Each of the bottles in turn was then immersed in water in the pail which contained the barley stems, so that they could be inserted through the holes in the rubber without admitting air to the stems. After the stems were inserted the rubber dam was loosened so that it contracted about the stems, holding them tightly and preventing evaporation of water from the bottle. The rubber was then held in place by a rubber band around the neck of the bottle.

TABLE 2.— *Comparative transpiration of smooth-awned, rough-awned, rough-awned with the awns removed, hooded, and awnless barleys.*

Variety.	Type.	Transpiration by 10 heads (single determination) in grams.	Period of transpiration hours.	Average length of awn cm.
Manchuria (check)	6-rowed, awns rough	58.9	57.35	9.5
Manchuria (check) ½ awns clipped	6-rowed, awns rough	44.8	57.45	10.5
Manchuria (check) all awns clipped	....	24.5	58.15	......
Manchuria I–15–2	6-rowed, awns rough	76.1	58.40	12.0
Minsturdi	6-rowed, awns rough	58.7	58.35	9.5
Arequipa	6-rowed, awns rough	48.0	59.25	14.0
Trebi	6-rowed, awns rough	58.4	58.55	13.5
Meloy	6-rowed, hooded	28.4	59.20	......
Arlington awnless	Intermedium, awnless	19.3	59.20	......
II–20–9 Smooth Awn x Luth	6-rowed, awns smooth	55.6	57.45	10.0
II–20–8 Smooth Awn x Manchuria	6-rowed awns smooth	65.2	59.00	9.5
II–20–14 Arequipa x Smooth Awn	6-rowed, awns smooth	63.8	59.00	12.0
II–20–10 Smooth Awn x Luth	6-rowed, awns smooth	60.6	59.05	10.0
II–20–7 Smooth Awn x Manchuria	6-rowed, awns smooth	55.1	58.45	9.0

The bottles with heads inserted were placed near a window in the laboratory, the amount of water transpired being determined by weighing the bottles from time to time. The period of transpiration is not exactly the same for all varieties as they were moved about from time to time on the table and then weighed at random. The slight variations are not, however, of great importance.

The transpiration results (see Table 2) are of like nature to those previously reported by other investigators.

Meloy hooded, Arlington, awnless, and clipped heads of Manchuria gave off a total of 28.4, 19.3 and 24.5 grams of water respectively, while normal Manchuria gave off 58.9 grams (see Table 2). The five smooth-awned strains gave off from 55.1 to 65.2 grams and averaged 60.1 grams.

TABLE 3.— *Comparative transpiration of smooth-awned barleys, of rough-awned, and of rough-awned with the awns removed.*

Variety.	Transpiration by 10 heads, in grams. Test A.	Test B.	Test C.	Average.	Period of transpiration.	Average length of awns.
Manchuria (check)	83.2	74.2	81.2	79.5	47.05	9.5
Manchuria (check) clipped	28.7	25.3	25.3	26.4	46.45	....
II-20-8 Smooth Awn x Manchuria	67.1	72.8	69.7	69.9	46.45	8.5
II-20-9 Smooth Awn x Luth	62.7	59.0	74.0	65.2	46.55	10.0
II-20-10 Smooth Awn x Luth	82.1	80.0	79.9	80.7	46.55	9.0

A second experiment was made in which Manchuria and three smooth-awned strains were used, each experiment being run in triplicate. Two of the smooth-awned strains gave off somewhat less water than Manchuria, while one strain gave off a slight percentage more. (See Table 3.)

SUMMARY.

The awn of barley and wheat is an important physiological organ. Under various conditions it has been shown that awned varieties give higher yields than awnless. These results should be considered by plant breeders and farmers before deciding to grow only awnless varieties.

The use of smooth-awned strains of barley will, in a large measure, overcome the unpleasant features of handling rough-awned varieties. Comparative yield tests and comparative studies in transpiration of heads of smooth- and rough-awned varieties indicate that smooth-awned barleys have no physiological limitations when compared with standard rough-awned varieties.

LITERATURE CITED.

1. GRANTHAM, A. E. Wheat investigations — varieties. Del. Agr. Exp. Sta. Bul. 121. 1918.
2. ——— Bearded vs. smooth wheats for Delaware. Del. Agr. Exp. Sta. Ext. Bul. 6. 1919.
3. HARLAN, H. V. Smooth-awned barleys. *In* Jour. Amer. Soc. Agron. v. 12: 205–208. 1920.
4. ——— and ANTHONY, STEPHEN. Development of barley kernels in normal and clipped spikes and the limitations of awnless and hooded varieties. *In* Jour. Agr. Res. v. 19:431–472. 1920.
5. ———and HAYES, H. K. Breeding investigations. *In* Minn. Agr. Exp. Sta. Bul. 182: 45–56. 1919.
6. HAYES, H. K. Inheritance of kernel and spike characters in crosses between varieties of *Triticum vulgare.* In Press.
7. PERLITIUS, LUDVIG. Der einfluss der begrannrung auf die wasserverdunstung der ähren und die kornqualität. Merseberg, Inaug-Diss. Breslau. 77 pp. 1903.
8. SCHMID, B. Bau und functionen der grannen unsere getreidearten. Bot. Centralblatt, v. 78: 328–330. 1898.
9. ZOEBL, A. and MIKOSCH, C. Die function der grannen der gerstenähre. Sitzber, K. Akad. Wiss. (Vienna) Math. Naturw. Cl., Band 101, Abt. 1, pp. 1033–1060. 1892.

THE EFFECT OF NITRATES APPLIED AT DIFFERENT STAGES OF GROWTH ON THE YIELD, COMPOSITION, AND QUALITY OF WHEAT.[1]

JEHIEL DAVIDSON.[2]

INTRODUCTION.

An experiment on the effect of sodium nitrate, applied at different stages of growth, on the yield, composition, and quality of wheat, previously conducted by this laboratory (1)[3], showed that when applied during the early part of the vegetative period sodium nitrate increased the yield of the crop, when applied at the time of heading it improved the quality of the grain, and when applied at the beginning of the milk stage it had no effect on the yield or quality of the crop.

In the experiment reported in this paper, the vegetative stage was subdivided into three periods. Each of three corresponding sets of plots received an application of nitrates at one of these periods.

[1] Contribution from the Plant Chemical Laboratory, Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C. Received for publication, December 2, 1921.

[2] Soil Chemist.

[3] Reference by number is to "Literature cited," p. 122.

The object of the experiment was to determine whether the effectiveness of the nitrates in increasing the yield of the crop disappears sharply when applied at a certain critical stage of development or disappears gradually when applied as the season advances toward the completion of the vegetative stage.

The experiment was carried out in the year 1919, at College Park, Maryland.[4]

PLAN OF THE EXPERIMENT.

For certain reasons, which need not be discussed here, it was considered desirable to compare the effects of sodium nitrate with those of calcium nitrate. To determine the effects of the bases (sodium and calcium), additional plots were treated with sodium nitrate and calcium sulphate and calcium nitrate and sodium sulphate. For the sake of further control, plots which received calcium sulphate and sodium sulphate alone were added. The experiment was carried out in duplicate. Samples taken in the remainder of the field by the small plot harvester (2) served as controls. Owing to the general lack of uniformity in the field, however, it is best to regard the twenty-four plots which received nitrates as separate sets of three plots corresponding to the three subdivisions and compare the plots with one another in every set. The plots, which were one square rod, with two-foot alleys between them, were laid out after the crop was up.

DIAGRAM 1.— *Description of plot treatments and the order in which they were laid out.*

No. plot	Fertilizer	Period	No. plot	Fertilizer	Period	No. plot	Fertilizer	Period
1	Sodium nitrate...	1	13	Calcium nitrate + sodium sulphate	1	25	Calcium sulphate.	1
2	"	2	14	"	2	26	"	2
3	"	3	15	"	3	27	"	3
4	Calcium nitrate..	1	16	Sodium nitrate + calcium sulphate	1	28	Sodium sulphate..	1
5	"	2	17	"	2	29	"	2
6	"	3	18	"	3	30	"	3
7	Sodium nitrate + calcium sulphate	1	19	Calcium nitrate..	1	31	Calcium sulphate.	1
8	"	2	20	"	2	32	"	2
9	"	3	21	"	3	33	"	3
10	Calcium nitrate + sodium sulphate	1	22	Sodium nitrate...	1	34	Sodium sulphate.	1
11	"	2	23	"	2	35	"	3
12	"	3	24	"	3	36	"	2

The plots were laid out in the order shown in Diagram 1. The soil was a Susquehanna loam. The seed was a China red soft winter

[4] Occasion is here taken to acknowledge the assistance of Director Paterson and Professor J. E. Metzger of the Maryland Experiment Station.

wheat. The date of application of the fertilizers for the plots of the first period was April 11, for those of the second period, April 24, and for those of the third period, May 14. The chemicals were applied at the rate of 320 pounds an acre — 2 pounds to each plot.

YIELD OF CROPS.

Photographs showing the difference in the stands on the plots receiving three different applications were taken when the wheat was fully headed. The weights of the entire crops were taken immediately after harvesting and again before threshing. While there was an appreciable loss of weight between the two weighings, the same general tendency was apparent in each case. The figures in Table I are the results of the last weighings. The weights of the grain were taken immediately after threshing.

TABLE I.— *Yields and percentage of grain.*

Treatment.	Period	Weight of crop.			Weight of grain.			Percentage of grain.		
		1st series	2nd series.	Average.	1st series.	2nd series.	Average.	1st series.	2nd series.	Average.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per-cent.*	*Per-cent.*	*Per-cent.*
Sodium nitrate.......	1	37	39	38.0	10.6	9.5	10.05	28.7	24.3	26.5
	2	34	25	29.5	9.5	6.4	7.95	27.9	25.5	26.7
	3	24	16	20.0	8.2	4.7	6.45	34.1	28.5	31.3
Calcium nitrate......	1	39	37	38.0	11.6	9.5	10.55	29.8	25.7	27.7
	2	36	30	33.0	10.2	9.0	9.60	28.5	30.0	29.2
	3	32	25	28.5	9.1	7.5	8.30	28.3	30.0	29.1
Sodium nitrate and calcium sulphate...	1	40	30	35.0	9.7	8.4	9.05	24.2	28.1	26.1
	2	30	24	27.0	8.0	6.4	7.20	26.7	26.5	26.6
	3	21	20	20.1	6.9	6.2	6.55	32.7	31.3	32.0
Calcium nitrate and sodium sulphate.	1	40	40	40.0	10.1	10.6	10.35	26.5	26.4	26.4
	2	30	31	30.5	7.2	8.1	7.65	24.0	26.6	25.3
	3	16	24	20.0	5.8	7.2	6.50	36.3	30.2	33.2
Calcium sulphate.....	1	23	13	18.0	7.8	4.3	6.05	33.9	33.3	33.6
	2	21	15	18.0	6.8	5.2	6.0	32.1	34.4	33.2
	3	30	14	22.0	9.6	4.6	7.1	32.1	32.8	32.4
Sodium sulphate.....	1	18	13	15.5	6.0	4.7	5.35	34.2	34.2	34.2
	2	13	12	12.5	4.7	4.2	4.45	37.5	37.5	37.5
	3	17	8	12.5	5.5	2.6	4.05	32.4	34.2	33.3
Control.............	....	17.4	18.6	18.0						

Both photographs and weights show strikingly that the effectiveness of nitrates in increasing yields gradually decreases as the time of application approaches the season of heading of the grain. The plots which received their nitrate application at the first period gave the highest yields; the plots which received it at the second and third periods followed in regularly diminishing order. This is true of the grain as well as of the entire crop. Altogether eight sets

of three plots each received nitrates, and in no case was there a single exception from the general rule.

In the majority of cases, the percentage of grain to crop is greater on the plots which received the nitrate application at the third period.

It is impossible to draw any conclusion as to the effect of the sulphates on yield. The yield variations from the plots which received sulphates alone do not consistently follow any principle. They seem to be caused largely by natural variations in the field.

QUALITY AND COMPOSITION OF GRAIN.

The wheat, being of a soft winter variety, did not exhibit the characteristics of typical "yellow berry" or "flinty" grain. Its general variation in color from yellow to brown, however, conformed distinctly to the order of the time of application of the nitrates. The grain from the plots which received nitrates at the third period especially was decidedly more brown than that from the plots which received the nitrates at the other two periods.

TABLE 2.— *Percentage of protein (nitrogen × 5.7) in grain.*

Treatment.	Period.	Protein. 1st series. *Percent.*	2d series. *Percent.*	Average. *Percent.*
Sodium nitrate....................	1	13.13	12.53	12.83
	2	13.92	12.97	13.44
	3	15.59	14.47	15.03
Calcium nitrate..................	1	12.47	12.37	12.42
	2	13.07	13.10	13.08
	3	14.44	14.68	14.56
Sodium nitrate and calcium sulphate.	1	13.04	12.22	12.63
	2	13.54	12.82	13.23
	3	15.00	14.12	14.56
Calcium nitrate and sodium sulphate.	1	12.75	12.33	12.64
	2	12.93	13.95	13.44
	3	14.11	14.91	14.51
Calcium sulphate..................	1	11.32	11.27	11.29
	2	11.38	11.17	11.27
	3	11.90	10.82	11.56
Sodium sulphate..................	1	11.14	11.25	11.19
	2	11.18	11.12	11.15
	3	11.26	10.92	11.09
Control	...	11.90	.....	.....

Without an exception the protein content (N x 5.7) increased regularly as the crops at the time of application advanced toward heading (see Table 2). While the grain on the plots which received their application at the second period showed consistently higher nitrogen contents than that on the plots which received it at the first, the differences are not considerable. The grain on the plots which received their application at the third period, which was

close to the time of heading, and which gave the lowest yields, showed appreciably increased nitrogen contents. It will be noted that the protein content of the grain on the plots which received their application at the first period was higher than that of the grain from the control and sulphate plots. The grain on the sulphate plots had a lower protein content than that on the control plot. Unfortunately the analysis of only one control sample is available. The figures from the sulphate plots, taken by themselves, however, seem to indicate a depressed nitrogen content.

The ash and phosphoric acid contents of the grain were also determined. As the results exhibit no consistent tendencies, they are not given here.

SUMMARY.

The period between the resumption of growth of wheat in the spring and the time of heading was divided into three sub-periods. Each of three corresponding sets of plots received nitrates at one of these sub-periods. The results thus obtained show that:

1. The effectiveness of nitrates in increasing yields decreases consistently as the time of their application approaches the stage of heading.

2. The effectiveness of nitrates in increasing the protein content (N x 5.7) of the grain increases as their effectiveness in increasing the yield decreases.

LITERATURE CITED.

1. DAVIDSON J., and LA CLERC, J. A. The effect of sodium nitrate applied at different stages of growth on the yield, composition, and quality of wheat. *In* Jour. Am. Soc. Agron. v. 9, 145-154 (1917); and v. 10, 193-198 (1918).
2. McCALL, A. G. A new method for harvesting small grain and grass plots. *In* Jour. Am. Soc. Agron. v. 9, 138-140 (1917).

A PLEA FOR EXPERIMENTAL WORK IN CROPS TEACHING.[1]

S. B. HASKELL.[2]

My interest in this subject dates back to the time when, as an instructor in an agricultural college, I vainly attempted to place crop teaching on a sound pedagogical basis. In time, I passed on to my successor this problem, still unsolved. Later on, as opportunity came, I made random observations on crop teaching as done at some twenty-six of the agricultural colleges. I talked with instructors, I talked with the students, I studied catalogs. I compared crop courses with soil fertility courses, likewise with courses in what is called fundamental science. Opportunity has never come to make such a study of the subject as is warranted by its importance. My conclusions, however, frankly based upon the above-mentioned more or less random observations, are as follows:

1. Crop credits are generally recognized by students as being cheap credits. The amount of time required outside of class is relatively low; the intensity of attention in the class is seldom high.

2. The mental training value of crop courses is open to question. They certainly do not compare favorably in mental training values with courses in science.

3. Observation training values are fair, although oftentimes not correlated with mental training.

4. The work required, at those places where the credit hour in crops has a real significance, is largely routine in its nature.

5. Crop courses as taught are oftentimes not founded on science. Men without the scientific training advertised as prerequisite have no difficulty in keeping pace with students who have taken the so-called fundamental science prerequisites.

6. In some rare cases, where a real attempt is made to found the work on science, there is duplication of effort inside of the institution, in that the science itself rather than its use as a tool is taught, under the guise of technical subject matter.

While the foregoing are merely statements of opinion, they are susceptible to proof or disproof. To determine the facts on the first three points, we must go directly to students who have taken or are taking courses in crops. The testimony of their instructors

[1] Paper read at the meeting of the Society held at New Orleans, La., November 8, 1921.

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is relatively of little value. Instructors theorize on what ought to be the results of the methods of teaching followed. Students base their statements on the actual experiences which they are undergoing. Not until crop instructors as a whole study the reaction of students to crop teaching as it is done can we expect the work to be on a sounder basis. The validity of the fourth charge, however, can in a measure be determined from a study of laboratory, lecture, or other class outlines. The use made of prerequisite science courses can be determined by a study of records of students in crops who have or have not taken these science courses, also of the course as outlined for men of different degrees of previous training. To obtain the facts as to the last assertion, we must get both the statements of instructors and the statements of the students. The final complex will establish the justice, or otherwise, of the charge made.

For the sake of argument, let us assume that my assertions represent facts. The state of affairs as pictured is not recent. I remember that at the meeting of the American Society of Agronomy held at East Lansing in 1912, Professor W. M. Jardine, now President of the Kansas Agricultural College, made the statement that "Our crop courses are cheap," and supported it in his usual vigorous manner. To give emphasis he reiterated the charge again and again, and certainly succeeded in getting marked attention. This, however, was nearly ten years ago; hence the question "Have our crop teachers made progress during the last decade" is entirely legitimate. If not, is the fault due to the limitations, inherent limitations it may be, of the subject matter. Or, is the basic trouble in our own limitations as crops teachers.

That there has been absolute progress in the last decade must be admitted by any impartial student of agricultural teaching. Remember, however, that progress is of two kinds, relative and absolute; and some of us will deny the relative progress in crop teaching methods. As an illustration of this, the past decade has seen instructional work in soils and soil fertility elevated from the kindergarten class to a rank second to no subject taught in agricultural colleges. Ten years ago, students were required to spend endless and expensive hours in the soil laboratory. They weighed and reweighed brass tubes, and powdered mineral matter which they fondly hoped represented soils; and estimated moisture on the surface and in the interior of all sorts of things. Yet when the attempt was made to bring together the scattered knowledge thus developed, and figuratively speaking to "cash in" on the laboratory technique so developed, the work left much to be desired. Today,

however, the subject of soils and soil fertility is recognized as being on the plane of interpretative science. Its function is to draw from all science such facts as apply to the problems of fertility and soil management. Its success as a college course is based largely on the fact that the mental training value of work so given was early apparent. The men attracted to soil courses were of the highest degree of ability. The real question at issue, therefore, is whether our crop courses have relatively lost or gained when compared with those other courses which compete with the study of crops for the time and attention of the student.

THE FUNCTION OF THE COLLEGE COURSE IN CROPS.

Crop production itself ranks as an art. By no stretch of the imagination can it be called a science. The term "scientific crop production" is an anomaly. True it is, however, that certain practices in crop production may have a sound foundation in science, or the reverse may be the case. If, however, the college subject of crops is taught as an art, then we are elevating to college rank something that really belongs in the vocational school. Such schools aim primarily to teach how to accomplish or to do certain things. The college course in these subjects aims at — come to think of it, just what is the aim of a college course in crops? Has it ever been defined in any effective sort of way? Has the line of demarcation between the vocational school course in crops and the college course in crops ever been established?

I must turn aside from the general subject of crop courses for the minute to make a statement of three platitudes, on which I shall base as a conclusion what I conceive to be a sound definition of the objective of the college course in crops. These platitudes are:

1. The function of a college is to teach men to think clearly. In this the college differs from a school, the function of which is to teach how to do.

2. The function of a vocational college, then, is to teach men how to think clearly, rapidly, soundly and constructively in terms of a vocation.

3. The function of an agricultural college, therefore, is to teach men to think constructively, productively and efficiently in terms of agriculture as a vocation.

Finally, and as a conclusion, the function of the college course in crops is to teach men how to think, constructively and productively, in terms of problems of crop production. As a corollary, it must teach students to see what there is to be seen, and to reason accurately and rapidly, from these observations, to sound conclusions.

Now if we accept these statements as sound we have at once a basis on which we may evaluate methods of crop teaching. We may judge of their value or their lack of value by the extent to which they promise the economical attainment of the objectives just stated.

WHY NOT EXPERIMENTAL WORK ON TEACHING METHODS?

At meetings of the American Society of Agronomy, at our local meetings of the New England section of this society, in conferences with crop and soil teachers all over the northeastern quarter of the country, I have heard much of curricula — of the place occupied by crop courses in these curricula — of relationship of crop courses to what are called prerequisite science courses — of the relationship of the study of crops to the study of soils, of farm management, and of various other similar subjects. I have been impressed with the utter futility of much of this discussion. It deals with the mechanics of arrangement, but does nothing, absolutely nothing, toward placing the teaching of crops on a sound pedagogical basis. In fact, it is useless to discuss the place of crop courses in the curriculum unless the major objective of these courses be clearly defined. The failure of such courses, if grouped in one place, will be no less serious than if grouped in another. Furthermore, unless the students are inspired or even compelled to use as tools the subjects required as prerequisites, then these same prerequisites are practically non-essentials. They may indeed be included for their mental training values, but if so this should be so admitted frankly and freely. Opinions may differ as to the importance of these prerequisite sciences in the study of crops. There can be no difference of opinion as to the necessity of clear realization of just why such courses are included in the curriculum. Now, contrasting strongly with eternal discussion on the mechanics of arrangement, we seldom hear of crop teaching in its human relationships, nor yet of the relative value of different methods of attaining the prime objectives — which, let me repeat, should be increased ability on the part of the student to really think in terms of his subject matter. This brings me to a suggestion which I make with some hesitation — why should not the American Society of Agronomy do experimental work in determining the final values of different methods of crop teaching? There is real need for this service. The time our students spend in crop courses is expensive. As crop instructors we cannot afford to have our courses of any less value to the men taking them than are other courses, regardless of what they may be, which are offered in an agricultural college.

AN OPPORTUNITY FOR SERVICE.

I look upon this suggestion as a presentation to the American Society of Agronomy of an opportunity for real service. In order to render possible easy criticism of the suggestion, I will present it in the form of three steps which I believe should be taken. These are:

1. Determine the facts as regards crop teaching as actually being done. I have presented nothing more than an opinion based upon more or less consistent, but nevertheless random, observation. I may have overdrawn certain things in the picture which I attempted to present. Therefore let the American Society of Agronomy determine the facts and publish the same without fear of favor. This is the first big service which may be rendered by the Society.

2. Make a critical study of teaching methods now in use. Define objectives. Find how different instructors aim to compass the same objectives. Catalog these methods.

3. Outline definite experiments in methods of teaching. Select a number of methods designed to attain the same objective, test them out in different institutions, in different classes in the same institution, on different individuals in the same classes. Develop machinery for measuring, no matter how inefficiently, the reaction of the student. Evaluate our crop teaching methods in terms of the human element rather than in terms of the subject matter itself.

Of necessity, before we can take action or organize work on recommendation No. 3, recommendations Nos 1 and 2 must be acted upon. In case it is possible, however, to organize the work outlined in No. 3, I must emphasize that the basis of final judgment must be the reaction of the student, the interest aroused in him, the type of men attracted to crop courses, and the ability of the student, once exposed to our crop teaching, to apply scientific thought to subject matter problems, and finally, his ability to see clearly and reason accurately from that which he has seen.

Does this represent an easy program? No. A necessary program? I believe the answer must be in the affirmative. Yet I believe that the work, onerous though it may be, will be worth while for the sake of the good standing of one of the most important courses in our agricultural colleges. Furthermore, we should always remember that the most serious waste in college is time waste; and that the least excusable of these time wastes is that which a student may be forced to waste in class or laboratory. Therefore the fundamental necessity of this study lies in the fact that it is incumbent upon us to guarantee the essential worthwhileness of the time spent by students, in crop studies.

REPORT OF THE COMMITTEE ON LECTURES FOR A STANDARD INTRODUCTORY COURSE IN FIELD CROPS[1]

In offering an outline for the lectures of a standard *introductory* course in Field Crops, the Committee feels that some discussion of its choice and organization of subject matter is desirable, by way of explanation and emphasis.

Is a Standard Introductory Course Desirable?— The Committee defines this course as a selection and organization of the introductory subject matter of Field Crops, which can be taught with considerable uniformity among the leading agricultural colleges of the country. The Committee believes a standard course is not only desirable but necessary, if Field Crops is to grow in power and dignity as a distinct part of the agricultural college curriculum. In the judgment of the Committee the course will have two highly important functions — (1) it will provide a basis for the accurate adjustment of credit when students leave one college to enter another and (2) it will provide a basis for improvement to which teachers may systematically contribute. The Committee considers the latter function extremely important. There is now a great opportunity for constructive work in the science of teaching our subject, and the Committee believes that if teachers can accept a common basis for future development, research in this field will be greatly stimulated.

The Form of a Standard Course.— What then should be the form of the standard course? What subject matter should be chosen? With instruction in crop production as the principal aim of the Field Crops curriculum, an introductory course may be organized in either of two forms — (1) *individual treatment*, by which crops are studied separately, according to their historical and economic significance, their ecological and botanical relationships, their physiological processes, and the cultural methods by which they are produced or (2) *general or topical treatment*, by which the history, importance, relationships, processes, and cultural methods of all crops are grouped in a *topic outline* and developed in a broad fundamental way.

A standard course organized in the first form could have only a limited adoption. Not only do crops differ, but the best methods for their production differ between various parts of the country.

[1] Presented at the meeting of the Society held at New Orleans, La., November 8, 1921. (See minutes, Vol. 13, page 367.)

And a further objection may be raised against this form on the point of efficiency in teaching. There is a great deal of wasteful repetition in a course which deals separately with individual crops. So many of the facts discussed for one crop are repeated for others. This repetition progressively lessens the interest of the student and affords no mental stimulus for the teacher himself.

Neither of these objections apply to a course which deals largely with the principal factors underlying the production of all crops. Indeed the strength of this course parallels the weakness of the course organized on the basis of individual treatment. It can be very widely adopted. It emphasizes pointedly, rather than incidentally, the fundamentals of crop production. It can systematically give the student a general grasp of these fundamentals. It can impress him with the breadth and dignity of the subject. It is efficient, in its systematic special treatment of facts fundamental to the production of all crops; and it will stimulate the interest of teachers, since it offers a broader opportunity for constructive study and individuality in presentation. And finally, it will awaken the student to a better appreciation of the value of the basic sciences, since it so frequently affords the opportunity for applications of scientific facts to practice.

Assuming the superiority of the general or topical course, the committee recommends that the standard introductory course be organized in that form, and in the following outline we suggest a body of subject matter which we believe will be satisfactory for the lectures of such a course.

A SUGGESTED OUTLINE FOR LECTURES IN A STANDARD INTRODUCTORY COURSE IN FIELD CROPS.

LECT. I. DEFINITION OF THE PURPOSE AND SCOPE OF THE FIELD CROPS CURRICULUM.

- A. To give instruction in the successful production of crops.
  - 1. By surveying and discussing good methods and practices.
    - a. Those in use by good farmers.
    - b. Those that have developed from experimental evidence.
    - c. Those indicated by experimental evidence.
  - 2. By discussing significant developments in agronomic research and investigation.
  - 3. By deductions and theories based on facts learned by experience and experimentation.
- B. To vitalize for the student the basic sciences — botany, chemistry, physics.
  - 1. By explaining and illustrating the known relations of many scientific facts to good practices in crop production.
  - 2. By suggesting other possible relations.
- C. To illustrate in a special way the influence of crops upon economic conditions.

LECT. II. CLASSIFICATION OF FIELD CROPS.

A. Botanical groups — grasses, legumes, others — and their relationships.
B. Agronomic groups — grain, forage, fiber, root, etc., etc., etc.
C. Special purpose groups — cover, catch, green manure, soiling, silage nurse, etc., etc., etc.

(In this lecture Ball and Piper's glossary of agronomic terms — see Journal, of Agronomy — should be assigned for class study and its value explained.)

LECT. III. THE ECONOMIC SIGNIFICANCE OF FIELD CROPS.

A. Crops the basis of world trade.
B. Crops the basis of farm wealth.

LECT. IV. RELATION OF GOOD CROPS TO GOOD TIMES.

A. General prosperity and progress depend upon a stable supply of cheap food.
B. Crops the most important and cheapest source of food.
  1. Why food has been cheap in the past.
    a. Free or cheap land.
    b. Cheap labor.
    c. Invention of labor saving machinery.
  2. Future production of cheap food.
    a. The maintenance of soil fertility.
    b. Improved cultural methods.
    c. Improved varieties.
    d. Control of enemies — diseases, insects, etc.
    e. Economy of labor.
C. Need of a national policy in crop production.
  1. To promote the maintenance of soil fertility.
  2. To stabilize the production and disposal of crops, so that profits may be justly distributed.

LECT. V. RELATION OF GOOD METHODS OF CROP PRODUCTION TO PROFIT.

A. Good methods and the economy of labor.
B. Relation of general high production to profit.
C. Relation of individual high production to profit.
D. Most productive methods not necessarily the most profitable.

LECT. VI. DISTRIBUTION OF FIELD CROPS.

A. As influenced by the various characteristics of climate, especially the length and nature of the growing season.
B. As influenced by the character of the soil.
C. As influenced by economic and social conditions.

LECT. VII. THE RIGHT CROP IN THE RIGHT PLACE.

A. The soil must be suitable for the crop.
  1. Choice of soil in relation to the needs of the crop to be grown. Examples and explanations.
  2. Cultural modifications of soils for crop needs.
    a. Irrigation.
    b. Drainage.
    c. Terracing.
    d. Ridging on wet lands.
    e. Listing under dry conditions of soil and climate.
B. The crop must be adapted to the climate.
  1. Requirements of important crops for the characteristics of climate.
  2. Nature and effects of drought and winter-killing.

LECT. VIII. THE VALUE OF GOOD VARIETIES.

A. Local differences between good varieties and poor ones.
B. Values of some famous varieties.
C. Range of varietal form in important crops.
  1. Varietal distinctions.
    a. Morphological.
    b. Physiological.

2. Stability of varietal distinctions.
    a. As affected by climate.
    b. As affected by soil.
    c. As affected by mixtures.

LECT. IX. PLANT IMPROVEMENT.

A. Possibilities of profit from plant improvement.
B. Methods of plant improvement.
    1. Selection — mass and pedigree.
    2. Hybridization.
C. Some notable accomplishments in plant improvement.
D. Relative importance and limitations of plant improvement.
E. Plant improvement under farm conditions.

LECT. X. THE VALUE OF GOOD SEED.

A. What is good seed?
    1. Its qualities.
    2. Conditions which affect qualities.
B. Profit in the use of good seed.
    1. Illustrations of its superior yield.
    2. Comparative value of its returns on the basis of the unit of investment.

LECT. XI. HOW TO SECURE GOOD SEED.

A. Practices in seed selection (See lecture IX).
B. Storage practices.
C. Seed testing.
D. Seed associations.
E. Seed laws, etc.

LECT. XII. PREPARATION OF THE SEEDBED.

A. Good preparation increases yield.
B. Statement and explanation of the benefits of good preparation.
C. Principles of preparation.
    1. Condition of the soil.
    2. Time of preparation in relation to climate, crop, soil type, etc.
D. Good methods of preparation for the most important local crops.

LECT. XIII. COMMERCIAL FERTILIZERS.

A. The uses and general effects of fertilizers.
B. Theories of fertilizer application.
C. Economy in the use of fertilizers.

LECT. XIV. BARNYARD MANURE.

A. Its benefit to crops and the probable reasons.
B. Economy in its use.
    1. Relative value for different crops.
    2. Time of application in relation to value.
C. Care of manure.

LECT. XV. LIME.

A. Its benefit to certain crops and the probable reasons.
    1. Crops which are benefited by lime and the general conditions under which lime should be used.
    2. Crops which are not apparently benefited by lime.
B. Commercial forms of lime.
C. Time and methods of application.

LECT. XVI. SEEDING PRACTICES.

A. Relation to kind and quality of seed.
B. Relation to climate, season, and time of seeding.
C. Relation to soil.
D. Rates and dates of seeding local crops, presented in tabular form.

LECT. XVII. GERMINATION OF THE SEED.

A. Seed structure.
B. Conditions for germination.
C. Process of germination.

LECT. XVIII. CROP GROWTH. (Optional, depending upon previous instruction in Botany.)

A. Sources of plant food.
B. Probable way in which plant food and water is taken from the soil.
C. Photosynthesis and food storage.
D. Reproduction.

LECT. XIX. CROP TILLAGE.

A. Effects of tillage.
B. Theories of tillage.
C. Tillage practices with local crops.

LECT. XX. HARVESTING GRAIN CROPS.

A. Importance of timely harvesting.
  1. Losses from over-ripe crops.
  2. Losses from under-ripe crops.
  3. The proper stage for harvesting.
B. Harvesting methods for different grain crops.
C. Comparative value of different methods of storage — shocks, stacks, ricks, bins, cribs, etc.

LECT. XXI. HARVESTING FORAGE CROPS.

A. Importance of timely harvesting.
  1. Losses from over-ripe crops.
    a. Shattering, lodging, etc.
    b. Reduction in palatability and nutritive value.
    c. Reduction in yield of subsequent cutting.
  2. Losses from under-ripe crops.
    a. Loss in nutritive value.
    b. Loss in maximum yield of dry matter.
    c. Greater difficulty in curing.
  3. The proper stage for harvesting.
    a. General rules.
    b. The proper stage for harvesting local forage crops.

LECT. XXII. HAY MAKING.

A. Essential facts about curing hay.
  1. Changes in plant material during curing process.
  2. Relation of these changes to market quality of hay.
  3. Loss of substance during curing.
B. Practices in curing local crops.
C. Summary of general rules.

LECT. XXIII. ENSILAGE.

A. Economy of ensilage.
B. Changes in plant matter, green to cured — conditions of good ensilage.
C. Ensilage crops — choice, rate of planting, stage for cutting, etc.
D. Good practice in making and preserving ensilage from important crops of the section.

LECT. XXIV. SPECIAL PURPOSE CROPS.

A. Catch crops, cover crops, green manure crops.
B. Principles in their choice and production.
  1. Early, quick growing, aggressive varieties.
  2. Cheap preparation.
C. Examples of local catch, cover, and green manure crops.

LECT. XXV. PLANT ASSOCIATION AND COMPETITION.

A. Plant association in nature.
B. Plant association (mixtures) in cultivation.
  1. How plants may benefit by association.
  2. How plants may be injured by association.
  3. Principles in choosing plants for associated growth.
  4. Examples of successful and unsuccessful associations — reasons, etc.
C. How type of population is shifted by a change in the soil.
D. Aggressiveness in plants — advantages and disadvantages.

LECT. XXVI. PASTURE MANAGEMENT.

A. Importance of pastures.
B. Classification.
C. Cultural methods.
D. Seeding.
E. Carrying capacity.
F. The leading pasture grasses — general and local.

LECT. XXVII. MEADOW MANAGEMENT.

A. Uses and purposes of meadows as distinguished from uses and purposes of pastures — value in rotations, etc.
B. Meadow mixtures.
  1. Principles and practices.
  2. Plants adapted for local use.
C. Cultural methods.

LECT. XXVIII. THE WEED FACTOR IN CROP PRODUCTION.

A. Definition — weeds a competitor of crops, etc.
B. Damages and benefits of weed growth.
C. Classification and characteristics of weeds.
  1. Root habits.
  2. Growth habits.
  3. Seeding habits.
D. Control of weeds.
  1. Cultural.
  2. Smothering.
  3. Chemical sprays.
  4. Clean seed.
E. Summary of control methods.

LECT. XXIX. CROP ROTATION (GENERAL CONSIDERATIONS).

A. Effect of continuous cropping.
B. Development of fallow and rotation systems.
C. Reasons for crop rotation.
  1. Maintenance of yields.
  2. Distribution and economy of labor.
  3. Reduction of risk.
  4. Control of weeds, insects, diseases.

LECT. XXX. CROP ROTATION (PRACTICES).

A. Essentials of a good rotation.
B. Planning the rotation.
C. Examples of good rotation with local crops.
D. Difficulties and limitations of crop rotations.

LECT. XXXI. CROP DISEASES.

A. Economic importance of diseases of crop plants.
B. Some of the most important diseases.
  1. Their nature and causes.
  2. How they are spread.
  3. Life history of an important disease fungus.
C. The control of diseases in field crops.
  1. Curative measures too expensive to be practicable.
  2. Prevention of diseases.

LECT. XXXII. INSECT ENEMIES OF FIELD CROPS.

A. Economic importance of crop insects.
  1. How and to what extent they damage crops.
  2. Life history of an important insect enemy of field crops.
B. The most important crop insects.
C. Prevention of insect attack.
  1. Rotation.
  2. Clean farming.
D. Control of insects — measures for a few important cases, selected to illustrate general principles of control.

LECT. XXXIII. GRAIN GRADING.*

A. Early establishment of grades.
  1. Faults of early grades.
  2. Conditions which led to Government investigation.
B. Federal grades.
  1. Establishment.
  2. Advantages.
  3. Processes in grading.
C. Federal supervision of grades, organization, etc.
D. Licensed and State inspectors.

LECT. XXXIV. GRAIN MARKETING.*

A. Time of marketing.
B. Transportation to local market.
C. The local market and its value.
D. The central market.

LECTS. XXXV — XLV. A SUMMARY OF INFORMATION ON THE PRODUCTION OF LOCAL CROPS.

In these lectures (XXXV–XLV) the most important local crops should be treated individually, giving to each crop the time its relative importance deserves. For example, three or four periods might be spent with corn, in which would be summarized from the general subject matter of the previous lectures all information that bears directly on good methods of corn production, together with such other practical information as the teacher wishes to include. The purpose of the summary is therefore to align, to review, and to supplement — in such a way that the student will receive definite instruction in good methods of local production, based upon the broad and fundamental considerations previously developed.

* The grading and marketing of cotton, tobacco, hay or potatoes may be substituted or added here, if desirable.

In preparing this outline the Committee requested of all departments of Agronomy or of Field Crops in the country (1) the outline of their present elementary courses or (2) their suggestions for the essentials of a standard course. Thirty-six replies were received, which number may indicate the degree of interest the matter holds for teachers in general. The majority of these replies presented the conventional outline for the individual treatment of crops; in some replies were found a few suggestions for topics similar to those composing the larger part of the outline now presented by the Committee; and the suggestions of a few teachers were decidedly in the direction of this outline. We therefore conclude that the

idea for a more fundamental introductory course is already in the minds of several teachers.

The Committee considers this outline by no means perfectly developed. *It is only an essential basis for further construction and improvement.* Details are purposely omitted, except when necessary to explain a topic heading or to illustrate the possibility of elaboration. The general purpose is to suggest and illustrate rather than to construct rigidly. Individual teachers may wish to modify some parts of the outline or to substitute other topics in conformity with local conditions. For instance, some may substitute for grain grading and marketing the grading and marketing of cotton, tobacco, potatoes, or hay; or include a general treatment of root crops; or broaden the topic "hay-making;" or reduce somewhat the economic considerations of crops (lectures III, IV, V). *Such modifications will not be contrary to our general idea, which is to deal mainly with fundamentals.* The outline is elastic enough for the reasonable adjustment of topics to local needs.

Some teachers may feel that at certain points the outline encroaches upon the subject matter of other departments. *However, it is not intended that discussions of subjects which might be classified as Soils, Botany, etc., shall proceed far into the technical fields of those departments.* For example, the discussion of lime would aim only to give the student essential information for the intelligent use of lime in crop production. To give such information must be a privilege and a duty of the course in Field Crops — a privilege, because we may properly deal with all the essentials of crop production; a duty, because many of our freshmen or sophomore students may not reach courses in other departments which deal specially with some of these vital subjects.

In suggesting this outline the Committee assumes that the standard course will be taught to freshmen or sophomores, that its presentation will require three lecture periods weekly during one scholastic term; that it will be supplemented by two laboratory periods, thus completing a five-hour course; and that it will be followed by advanced special electives, such as Grain Crops, Forage Crops, Fiber Crops, Field Crops Improvement, and Field Crop Management.

The Committee wishes to emphasize its allotment of 10 or 12 lectures for the treatment of individual crops in the latter part of the course. These special lectures will serve the double purpose of applying the fundamentals previously studied and of giving specific instruction in the production of local crops. The Committee believes this number will generally be sufficient, in view of

the previous study of fundamentals common to all crops, but it may be somewhat increased to serve local needs and the number of general topics adjusted accordingly.

Respectfully submitted,
W. C. ETHERIDGE,
M. L. FISHER,
COMMITTEE ON LECTURES FOR A STANDARD INTRODUCTORY COURSE IN FIELD CROPS

NITROGEN ECONOMY IN SOILS[1]

FIRMAN E. BEAR.[2]

COMBINED NITROGEN IN RAINWATER.

After listening to Liebig's lectures before the British Association for the Advancement of Science in 1840, Lawes and Gilbert returned to Rothamsted with the determination of testing the accuracy of his conclusions as to the sufficiency of the ammonia of the atmosphere as the source of the nitrogen of plants. Accordingly, arrangements were made for collecting the rainfall on a measured area with the result that the total combined nitrogen thus secured was estimated at 6 or 7 pounds per acre. Later, more exact determinations summarized by Russell and Richards (30)[3] and covering the period from 1888 to 1916 showed an average acre content of ammoniacal and nitric nitrogen in the rainfall amounting to 3.97 pounds. To this may be added that recorded as being in organic forms and estimated at 1.35 pounds per acre, making a total of 5.32 pounds from an average rainfall of 28.8 inches.

A review of the literature on this phase of the subject by Wilson (34) shows the nitrogen content of rainwater has usually been found to be from 5 to 8 pounds per acre annually. Occasional reports have indicated much larger quantities amounting to as much as 15 to 20 pounds. In his investigations at Ithaca, New York, covering the period from 1915 to 1920, Wilson found an average of 12.51 pounds per acre of ammoniacal and nitric nitrogen with a rainfall of 29.3 inches. It is questionable as to how correctly this average figure may represent the nitrogen in the rainfall. It is possible

[1] Paper read at the meeting of the Society held at New Orleans, La., November 7, 1921.

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[3] Reference by number is to "Literature Cited," p. 151.

that the high quantities noted for three years may be related to the enlarged industrial activities associated with the World War. For the two-year period from May, 1918, to May, 1920, the average was slightly less than 4 pounds per acre. Ames (1) reports the nitrogen content of the rainwater at Wooster, Ohio, at from 6 to 7 pounds per acre, with an average rainfall of 37.9 inches.

No very definite correlation is apparent between the amount of combined nitrogen in the rainwater and any contributing agent. In general it may be said that the amount tends to be larger with the increased rainfall and perhaps also with the nearness to industrial centers. Probably the quantity obtained over much of the humid sections of America would amount to not more than 5 to 6 pounds per acre annually.

FIXATION OF ATMOSPHERIC NITROGEN.

Ever since Wilfarth (33) reported the quantity of nitrogen contained in the inoculated as compared to the uninoculated lupins which he grew in pots filled with sand, investigators have been studying the efficiency of *B. radicicola* as a nitrogen fixing organism. The experiments designed to determine this have fallen largely into three groups:

1. Comparisons of the nitrogen content of legumes and non-legumes grown on equal areas of similar soil.
2. Comparisons of the nitrogen content of inoculated and uninoculated legume crops grown on equal areas of similar soil.
3. Analytical records of the nitrogen content of the soil of a given area before and after the growth of the legume, together with records of the nitrogen in the seed and water added and that removed in the crop and drainage water.

COMPARISONS OF THE NITROGEN CONTENT OF LEGUMES AND NON-LEGUMES.

As early as 1860, Lawes and Gilbert (22) pointed out that legume plants contained much larger amounts of nitrogen than non-legumes grown on the same soil. As an average of three years data, they had found the nitrogen content of the cereal crops at Rothamsted to be approximately 30 pounds per acre as compared to 120 pounds contained in clover. They wrote:

> "Ammonia cannot be procured in the market in any large quantities, but by cultivating turnips and the leguminous plants, a large amount of this substance is collected by them from the atmosphere."

However, the difference in nitrogen content of a legume and any given non-legume grown on the same land may not represent the nitrogen gained thru the agency of the legume and its associated

organisms, since the several non-legumes differ markedly in their capacity to take nitrogen from the soil. Hiltner (20) classifies the non-legumes into two groups, the " Stickstoffzehrer " and the " Stickstofferhalter " and of the latter group mentions in particular the rape plant. Analyses recorded by Henry and Morrison (19) show that this plant, in common with several well-known weeds such as purslane and field daisies, may contain percentages of nitrogen equal to or greater than that of red clover.

In this connection, the conclusion of Lyon and Bizzell (26), that the rate of nitrification in soils is very much influenced by the growing crop, is pertinent. Maize and clover were shown to have markedly stimulating effects on nitrate formation. Timothy and some of the grasses were found to depress nitrification. Of particular interest is the possibility that legumes, by reason of their favorable effect on nitrification, may thereby be enabled to secure larger amounts of nitrogen from that stored in the soil organic matter than is ordinarily supposed. If the comparison is to be between a legume and a non-legume perhaps a member of the " Stickstofferhalter " group should be selected.

COMPARISONS OF THE NITROGEN CONTENT OF INOCULATED AND UNINOCULATED LEGUMES.

Numerous examples of this type of investigation are found in the literature. Among the more recent may be mentioned the data reported by Arny and Thatcher (3) on first crop, second season, sweet clover and alfalfa grown on moderately productive soil. In their tests, it was shown that the nitrogen content of the former, calculated from the tops and roots produced on plots of three square yards, was increased at the rates of 133 and 76 pounds per acre by inoculation with and without an accompanying use of lime respectively. Similarly, 118 more pounds of nitrogen per acre were found in inoculated than in uninoculated alfalfa. Fred (12) found an increase from inoculation in the nitrogen content of the tops, roots and nodules of soybeans, calculated from the crops grown on areas of 137.5 square feet of Plainfield sand, amounting to 57 pounds per acre.

Such a method of calculation would apparently not exaggerate the nitrogen fixing capacity of the nodule organisms, since it is difficult to find an area of the legume crop which is not at least partially inoculated. However, the foraging power of the legume plant for soil constituents must be considerably increased as a result of the larger growth following inoculation. The work of Arny and Thatcher shows that not only are the quantities of the mineral

constituents in legumes thus increased, but that the actual percentage of potassium may be larger. The increase in the nitrogen content of legumes may therefore, represent a saving as well as a fixation. Taken in connection with the fact that legumes stimulate nitrification, this would throw considerable doubt on the validity of the argument that differences in nitrogen content due to inoculation represent the fixation by the nodule organisms of legumes.

The following conclusion of Hopkins (21) drawn from this type of investigation is interesting in this connection:

"On normally productive soils, one third of the nitrogen contained in legumes is taken from the soil, not more than two thirds being secured from the air"

COMPLETE ANALYTICAL RECORD OF NITROGEN ECONOMY IN THE SOIL AND CROP.

Of the more exact methods involving analyses of the soil, seed, and water, and of the crops removed, the pot tests of Hartwell and Pember (18) deserve particular mention. These investigators studied the nitrogen economy in Warwick sandy loam soil accompanying the growth of cowpeas, soybeans, crimson clover and adzuki beans, using vetch as a winter cover crop. Most satisfactory growth was reported for the first two. Summarizing their investigations they wrote:

"The approximate five-year net gain of nitrogen in the presence of these two crops, and the vetch which was grown alternately with each, was a ton of nitrogen per acre, about seven tenths of which was contained in the twenty-five tons of moisture free summer crop removed, and the remainder in the soil itself."

This indicates that the fixation processes may be quite rapid where the conditions are kept at or near the optimum. The original soil contained 0.1502 per cent of nitrogen. That in the soybean pots had a nitrogen content of 0.1987 per cent and of the cowpea pots of 0.1944 per cent at the end of the 5 year period. A point would probably soon have been reached at which the legume would have made larger use of the nitrogen previously fixed and made available thru nitrification.

NON-SYMBIOTIC PROCESSES.

The quantitive relationships which obtain in nitrogen fixation were found to be somewhat complicated when it was discovered by Winogradski and Beyerinck that certain of the organisms in soils, other than those which were known to produce nodules on the roots of legumes, were able to assimilate atmospheric nitrogen. Of these the *Azotobacter* group is credited with the greatest capacity. The conditions favoring their activities are now known to be quite similar to those suited to legume crops and include the presence of available phosphorus and potassium, carbonaceous materials and carbonates of calcium or magnesium, the latter according to Ashby

(4) appearing to be preferable. Opinions differ as to the capacity of these organisms to accumulate nitrogen under field conditions. Perhaps the statement of Lipman (23) has been most frequently mentioned in this connection:

"From the data at present available different investigators have estimated the quantity of nitrogen fixed by Azotobacter at 15 to 40 pounds per acre per annum."

The quantity of nitrogen assimilated from the air by non-symbiotic organisms is probably dependent, among other factors, upon the nitrate content of the soil. Nitrification is also favored by conditions similar to those suited to the needs of *Azotobacter*. Bonazzi (7) has recently shown that the presence of nitrates aids in the better utilization of the carbohydrates usually supplied in nitrogen fixation studies. It is his opinion that *Azotobacter* serve as nitrate conservers and that after the available nitrates have been utilized "a second physiological phase sets in, in which the cells assimilate atmospheric nitrogen." He writes further:

"It appears that 'all' organisms choose the line of least resistance for obtaining and assimilating their food; and micro-organisms are not an exception to the rule."

Investigations reviewed and extended by Fred (13) have shown that *B. radicicola* has the capacity to fix atmospheric nitrogen in the absence of its host. The experiment of Golding (15) in which the rate of fixation was increased by the removal of the soluble products of growth as produced indicates that this process might be considerably increased in the presence of growing plants which were withdrawing the nitrogen as it became available thru fixation processes. Even when the *B. radicicola* are working symbiotically the presence of a non-legume to serve in the removal of soluble nitrogen from the soil may be found desirable. A review of the data on this point together with supplementary investigations by Wright (35) indicates that it is not safe to assume, however, that the association of legumes and non-legumes always guarantees an increased nitrogen content of the non-legumes or an increased rate of fixation by the legume and its nodule organisms.

THE LYSIMETER METHOD OF STUDY.

Of all the methods employed in the study of the nitrogen economy of soils that in which use is made of lysimeters is perhaps to be preferred. Such tests approach somewhat more nearly to field conditions and yet provide for the checking up of the nitrogen outgo in the drainage water. An interesting record under such conditions of the nitrogen economy in Dunkirk clay loam soil having a nitrogen content in the first foot of 0.134 percent is provided by the work

of Lyon and Bizzell (27). In these investigations, it was found that the rate of loss of nitrogen in drainage from the manured soil was correlated rather definitely with the quantity of drainage water. The rather surprising feature of these investigations thus far is the relatively small amount of nitrogen in the drainage from cropped lysimeters. Excluding the first year, in which the loss was abnormally high due to the fact that the soil had been disturbed in moving and oxidation was probably considerably increased as a result, the average annual loss amounted to only 3.4 pounds per acre. Another important feature is the apparent confirmation of their conclusions, previously referred to, which indicate that the rate of nitrification is definitely related to the kind of crop being grown. For example, it was shown that the nitrogen losses in drainage were least in the presence of mixed grasses altho the nitrogen removed by them from the soil, as shown by analysis, was smallest of any of the crops under observation. In the absence of vegetation the nitrogen losses averaged nearly 100 pounds per acre annually, equal to half of the quantity applied in the form of manure.

The texture of the soil is a very important factor in determining the rate of nitrification and the subsequent loss of the nitrates in the drainage water. For this reason the problem is most serious in sandy soils, especially if they happen to be in a warm climate. The possibilities of losses under such conditions are shown in the lysimeter tests in Florida, as reported by Collison and Walker (9). However, as this experiment progressed and the trees in the tanks grew larger, the losses were very considerably curtailed by reason of the facts that a large part of the soil water was returned to the air by transpiration and more nitrate was utilized by the trees.

It is apparent that, in addition to the climatic and soil factors, the system of management which the soil receives will determine to a very large degree the point at which the drainage losses and the fixation processes will come to equilibrium. Nitrogen fixation is known to be stimulated by the use of potassium and phosphorus fertilizers and by the application of lime or limestone. In unproductive soils nitrogen fixation will be slow, but the nitrification processes are likely to be correspondingly slow. To accumulate nitrogen in the soil, nitrification need not necessarily be stopped, but both conserving and fixation processes must be in operation. It may also be possible, as suggested by Lyon (25) to grow acid tolerant legumes on soils in which nitrification has been retarded and thereby accumulate nitrogen. The critical pH of the nodule organisms of the soybean, for example, was found by Fred and

Davenport (14) to be 3.4 as compared to 4.3 for those of red clover and 5.0 for those of sweet clover and alfalfa. Salter finds that the critical point in the soil is approximately 1 pH higher than would be expected from culture solutions, due probably to the toxicity of the soluble aluminium. This would place the critical pH for nodule organisms of soybeans at 4.4. Nitrification in an acid DeKalb soil was found not to be accelerated to any considerable extent until the pH had been raised to 6, with a maximum between 6 and 8. It is possible, therefore, that a degree of acidity could be selected at which nitrogen accumulation could continue with a minimum loss of nitrate.

CYLINDER STUDIES.

When soils which are high in nitrogen are placed under cultivation the nitrogen content is rapidly reduced, because the nitrogen fixation processes cannot keep pace with the excessive nitrification and because even the legume crops do not require any considerable amount, if any, of nitrogen other than the nitrates produced. The nitrogen economy under such conditions is very nicely shown in the cylinder tests which have been carried out at the New Jersey Station (24). These studies were made on a light loam soil having an original nitrogen content of 4,975 pounds per acre ten inches. The cropping system was corn, oats, oats, wheat, timothy. From 1898 to 1907 the nitrogen content of the soil was reduced, on the phosphate and potash-treated cylinders, to 3,560 pounds. This represents a loss of 1,415 pounds of nitrogen of which only 415 pounds was accounted for in the crops removed.

Beginning with 1908, one series of cylinders was limed and fertilized with phosphate and potash salts and in addition a legume catch crop was turned under twice each five-year period. In this series the nitrogen content was reduced from 3,716 in 1908 to 3,274 in 1912, a loss of 442 pounds of which 231 was accounted for in the crops removed. By 1917, the nitrogen content of the soil had been reduced to 3,135 pounds, a further loss of 139 pounds. However, during this period the quantity of nitrogen removed in the crops amounted to 287 pounds. Apparently the point of equilibrium between nitrogen income and outgo had very nearly been reached.

NITROGEN ECONOMY STUDIES IN FIELD SOILS.

It will probably always be desirable to give our conclusions a final field test. Fortunately, it happens that crop records accompanying the regular and long continued use of fertilizing materials and definitely planned rotations are now available covering long periods of time, particularly at the Rothamsted, Pennsylvania and Ohio

experimental farms. It would seem as though it might be possible to check our conclusions on nitrogen economy by an investigation of the soils of these plots.

In 1885, Hall (16) called attention to what appeared to be a rather remarkable increase in the nitrogen content in soils allowed to run wild on the Rothamsted farm. Analyses of soil to a depth of 27 inches from such areas in the Broadbalk and Geescroft fields, before and after a twenty-year interval, showed an apparent average annual gain of 98 pounds per acre in the former and 44 pounds in the latter. The data were all the more remarkable when it was shown that the percentage of legume plants in the Geescroft field at the last sampling date was less than one-half of one percent.

It is interesting in this connection to examine the records of analyses of the soil of plot 5 of the continuous wheat series in Broadbalk field. This plot has received a complete mineral fertilizer but no nitrogen since 1852. Analyses of the soil were made in 1865, 1881, 1893 and 1914. Data for the first three analyses are given by Dyer (11) and for the last by Russell (29). They are as follows:

TABLE I.—*Estimated acre content of nitrogen of Broadbalk soil—complete mineral fertilizer plot—continuous wheat.*

Date.	First 9 inches.	Second 9 inches.	Third 9 inches.
1865	2782	1910	1708
1881	2543	1865	1597
1893	2517	1827	1563
1914	2517	1827	1680

The method of sampling in 1914, according to Russell, was comparable with that of previous samplings in so far as it applied to the surface 9 inches, but slightly different in the second and third depths. Considering only the first depth, the nitrogen loss amounts to 265 pounds per acre in a period of 50 years or a little over 5 pounds per acre per year. Crop records available for the 50-year period 1862–1911, which should be quite similar to those for 1865 to 1914, show that the average yield on this plot during this period has been 13.9 bushels of wheat and 11.2 hundred weight of straw, totaling 695 bushels of wheat and 560 hundred weight of straw, per acre. Subtracting 100 bushels of seed wheat would leave 595 bushels. With an estimated nitrogen content of 1.78 per cent for the grain and 0.475 for the straw, the total nitrogen removed by the crops during this period must have amounted to a little over 900 pounds or 19 pounds per acre per year.

Hall (17) estimated the annual drainage loss of nitrogen from this plot for the two years 1879–81 at 16.7 pounds per acre. This is

probably too high. The rate of loss has probably also decreased during more recent years. However, the drainage loss must certainly have equalled the gain in the rainfall, amounting to 5.32 pounds per acre. Even in the absence of legume crops, except the black medick which grows as a weed on these plots, and under conditions not particularly adapted to economizing in nitrogen, the assimilating process has kept pace with the removal after the total nitrogen content had fallen to approximately 2,500 pounds per acre-nine-inches.

In 1916, Bear and Salter (6) called attention to what appeared to be an increase of nitrogen amounting to 1,173 pounds per acre to a depth of 20 inches which had been accumulated in the soil of a plot on the West Virginia Experiment Station farm which had been liberally treated with phosphate and potash fertilizers and cropped in rotation for a period of 16 years. This figure was obtained from a consideration of the probable amount of nitrogen contained in the crops removed and from a comparison of the nitrogen content of the soil on this plot with that of an adjacent check. This accumulation, amounting to 73 pounds per acre per year, which may represent a saving as well as a fixation, had taken place in a silt loam soil having a nitrogen content of approximately 2,000 pounds per two million of surface soil, under conditions in which a legume crop was grown every fourth year. An interesting phase of this investigation was shown in the fact that there was almost a direct correlation between the phosphorus, nitrogen and carbon content of the soils of all the plots at the end of this period. This correlation was found to obtain in analyses of 240 soils chosen from various sections of West Virginia, a high content of phosphorus being invariably associated with high nitrogen content.

Later, from an examination of the records of the crop yields on similarly fertilized series at Wooster, Ohio, which had received additional applications of lime, the writer concluded that nitrogen fixation had progressed on these plots during the 25 year period of the test to the extent of 1,100 pounds per acre or 44 pounds per acre per year. Analyses of the soil were not then available. Since that time Ames (1) has reported the nitrogen content of the soil on plot 8 of section D of this series from samples chosen at several different time intervals. It seems desirable, therefore, to recalculate the data for the period since 1904, when the first application of lime was made. The record for the plot shows that it was in corn in 1904, oats 1905, wheat 1906, clover 1907 and timothy 1908 with the same crop sequence from that date forward, yields being available up to and including the wheat crop of 1921. The corn, oats, and wheat

have each been fertilized with acid phosphate and muriate of potash in amounts per acre totaling, for the period, 1,280 pounds of the former and 1,040 pounds of the latter. The west half of this plot was limed in 1904 and has been relimed as needed since. The east half of the plot has not received any lime. The following table gives the actual yields of crops for the period and the estimated number of pounds of nitrogen contained in them, calculated on the acre basis.

TABLE 2.—*Estimated nitrogen content per acre of crops removed—phosphate and potash treated plot—Wooster, 1905–21.*

Crops.	Frequency.	West half limed. Yield, hundred weight.	West half limed. Nitrogen, pound.	East half unlimed. Yield, hundred weight.	East half unlimed. Nitrogen, pound.
Corn	4	126.3	190.3	84.3	126.9
Stover	4	83.8	68.2	64.8	52.7
Oats	4	75.5	152.0	63.6	128.1
Straw	4	102.1	59.3	87.5	50.8
Wheat	4	64.5	127.4	44.7	88.4
Straw	4	100.6	53.1	61.2	32.3
Clover	3	97.1	210.5	33.5	72.7
Timothy	3	129.9	109.2	71.2	59.9
Totals		779.9	970.0	510.8	611.8

In estimating the nitrogen content of the crops removed, the average analyses of crops as reported by the Chemistry Laboratory of the Ohio Agricultural Experimental Station were employed. Ames, Boltz and Stenius (2) have shown, in a study of wheat samples selected from the several plots receiving various fertilizer treatments, that the nitrogen content of the wheat from the plot receiving phosphate and potash salts was only approximately 90 per cent of the average. Using this factor on all of the crops, the above figures for nitrogen would have to be corrected to 873 and 550 respectively.

On examining the records of the analyses of soil, it is found that this plot was sampled in 1907 and 1912. On request, Ames resampled the plot in 1921. The records of these analyses are given below:

TABLE 3.—*Estimated nitrogen content per acre of Wooster soil—phosphate and and potash treated plot.*

Dates.	West half limed, pounds per acre*	East half unlimed, pounds per acre*
1907	2000	1860
1912	2060	1680
1921	1846	1660

* On basis of 2,000,000 of surface soil.

The 1921 sample shows a reduction in nitrogen. To be strictly comparable to the samples chosen in 1907 and 1912, the sampling should have been delayed to 1922 which is the year in which the clover crop is being grown, the sampling having always followed the removal of the clover crop. Assuming the usual benefit supposed to be derived from a good crop of clover on well fertilized and limed soil, it would again seem reasonable to believe that the nitrogen content of the limed soil was being maintained at approximately a constant level approaching 2,000 pounds per acre. The point of equilibrium in the unlimed soil under the conditions of the test was apparently reached at a point approximating 1,650 pounds of nitrogen.

Accepting this assumption, it would appear that nitrogen accumulation since 1904 had been proceeding on the limed end of this plot at a rate of 58 pounds per acre per year. To this must be added that which was lost in the drainage. From this must be subtracted that secured from the rainfall. Ames reports from 6 to 7 pounds per acre annually in the rainwater. That lost in the drainage will never be known. The lysimeter tests at Cornell would indicate that it was not in excess of 3.4 pounds per acre. From data reported by Dole and Stabler (10) and by Clarke (8) it is possible to check the accuracy of the lysimeter test as applied to large areas of land in Ohio. From their data, the amount of nitrogen in the Miami River above Dayton, in the limestone area of Ohio, as determined for the year 1906–07, indicated an annual acre loss from the soils of that watershed amounting to 4.4 pounds per acre. Similarly in the Muskingum River above Zanesville, in the sandstone and shale area of Ohio, the nitrate nitrogen amounted to 1.13 pounds per acre as applied to the entire watershed. The percentage of cultivated land is considerably higher in the watershed of the Miami. This is also true of the nitrogen content of the soil. By this method of calculation the estimated loss would at least not be too high. The results of the calculation indicate that on the whole the soil is rather economical with its nitrogen supply, as the lysimeter tests indicate, and that the loss in this manner has not kept pace with the gain in the rainfall.

White (32) reports analyses of the soil of two plots (15 and 24) of the fertilizer series on the Pennsylvania State College Farm. Plot 24 is one of the check plots, while plot 15 has been receiving phosphate and potash fertilizers. The rotation followed has been corn, oats, wheat, and clover. Subtracting the crop yields of the check plot from the phosphate and potash plots and calculating

the nitrogen removed in these increases gives an estimated total of 605 pounds per acre for the 35 year period.

Analyses of the soils show a nitrogen content of 0.130 per cent for that of plot 15 and 0.1525 per cent for that of plot 24. Assuming a weight of two million pounds per acre, gives a difference of 450 pounds per acre in favor of the phosphate and potash plot. This makes a total of 1,055 pounds of nitrogen unaccounted for. Either the larger crops produced from the use of fertilizer conserved the nitrogen of the soil more successfully or a nitrogen fixation which may have amounted to an average of over 30 pounds per acre per year was in progress.

The recent report of the nitrogen content of the soil on the plots of the fertilizer series at the Missouri station (28), after 25 years of cropping, is significant as indicating the tendency of certain crops to economize on the soil nitrogen. As would be expected from Lyon and Bizzell's conclusions, the nitrogen content under continuous cropping was maintained at the highest level on the timothy plots, second on the oats and wheat plots and third on the corn plots. Incidentally these results also indicate that considerable nitrogen fixation must have occurred in the soil of the rotation series plots where no fertilizers were used, otherwise the nitrogen content in the soil should have been very greatly reduced, as compared to the virgin soil, thru its removal in crops and in increased drainage losses. The actual loss recorded at the end of the 30 year period is given at only 10 pounds per acre foot below the 4,000 pounds in the virgin soil.

The investigations of Swanson (31), in which analyses are reported of the soils of old alfalfa fields as compared to nearby native sod, have been quoted by several writers as indicating that the nitrogen fixation processes had shown no cumulative effect. The remarkable feature of the data is brought out when the quantity of nitrogen which must have been removed in the alfalfa crops harvested is taken into consideration. Evidently the point of equilibrium was reached at a nitrogen content which made the alfalfa secure a large percentage of its nitrogen requirements from the soil air. This point of equilibrium occurred under Kansas conditions at an average of 3,650 pounds of nitrogen per acre seven inches of soil.

SAMPLING FIELD PLOTS.

There are certain well recognized difficulties involved in such methods of study, which throw doubt on the quantitive accuracy of the conclusions drawn. The method of sampling plots has never been standardized. Samples of soil selected from field plots in

the early days of already long continued tests could probably not have been duplicated, by the method of sampling then employed, even the same day. Bear and McClure (5) have recently made a detailed study of the nitrogen content of two plots of soil as it might have been reported from a variety of possible combinations in the selecting of the composite for analysis. The plots were resampled a few days later and the results compared with those previously secured. Altogether 720 separate nitrogen determinations were made. The investigation showed conclusively that the sampling of a plot can be duplicated the same day with considerable accuracy if sufficient borings are taken and the same number and location of borings are again selected. In most cases the analyses were almost exact duplicates or varied only from 20 to 40 pounds per two million of soil.

The selection of samples of soil after a period of years to correspond to those originally secured from the same plot is a difficult matter. Nevertheless, it seems to the writer that where plot areas are bordered with permanent sod strips or other precautions are taken to insure that the soil is confined to the original area, the difficulty is not insurmountable. Where plot treatments are begun and continued over long periods of time it seems highly desirable to measure rather accurately the quantitative outgo of not only nitrogen but also of other elements, as compared to the rate at which they are replaced. It must, of course, be recognized that certain movements of the soil itself or of substances in solution continue to take place. The action of water, wind, earthworms, insects and other agencies, while perhaps relatively insignificant in any one year, in most cases, may over long periods of time effect considerable changes in the soil. In the study of the number of earthworms in the soil we have found them present, in plots of soil on the Ohio State University farm which were covered with bluegrass, in numbers averaging over one million per acre. These were concentrated, at the time the numbers were estimated, in July, in the upper foot of soil. A part of the nitrogen accumulation on the land allowed to run wild at Rothamsted may be due to the fact that these undisturbed areas provided very convenient places for the concentration of the insect and animal population from nearby locations.

It is well to remember, however, that Wilfarth's original experiments showed that the entire nitrogen requirement of the lupin, under the conditions of the test, must have been taken from the air. This has been confirmed with other legumes when grown under laboratory control in the absence of all nitrogen save that in the seed.

It has also been very definitely established that the non-symbiotic organisms are not dependent upon any combined nitrogen but can effect nitrogen fixation in media entirely free from this element. The addition of a nitrate usually increases the growth of the inoculated legume and results in a marked increase in the development of *Azotobacter*. Apparently the nitrogen fixation processes are not sufficiently rapid to supply the legumes or its associated symbiotic and non-symbiotic organisms with all of the nitrogen which they could utilize in their growth processes. The ratio of the quantity which must be supplied thru nitrification processes to that which the nitrogen fixing organisms can secure from the air undoubtedly varies with the different legumes and with the conditions under which they are grown.

An examination of virgin soil will show that the largest quantities of nitrogen have been accumulated in swamps and in regions of rigidly cold and long winters. In either case, nitrification is practically at a standstill while nitrogen accumulation from the rainfall and from the fixation processes, while slow, may continue. These accumulations may represent vast expanses of time so that the quantity added each year may have been relatively small. The agriculturist is interested in nitrogen economy under conditions suitable to the growing of field crops in which case both the nitrification and nitrogen fixation processes are in operation with an equilibrium which may be established at any number of different points depending upon a variety of factors.

CONCLUSIONS.

The point of equilibrium between nitrogen income and outgo in soils varies with many factors. Temperature, rainfall, soil reaction, cropping system, fertilizer treatment and soil texture are some of these factors. In northern latitudes with a cool climate, the nitrifying process is slower but there is undoubtedly a corresponding reduction in the rate of nitrogen fixation. In southern latitudes nitrification is more rapid and, with indifferent cropping systems, the total nitrogen content of the soil may be reduced to a very low point. With the adoption of suitable rotations, accompanied by a logical fertilizer program, nitrogen fixation processes are likely to be sufficiently rapid to compensate for the greater loss of nitrates in the drainage. With rather ordinary farming methods, nitrogenous fertilizers are likely to be more effective in Michigan, Wisconsin and the Dakotas or in Florida, Louisiana and Texas than they are in Ohio, Illinois and Iowa.

As the soil reaction becomes increasingly acid the rate of nitrification is reduced. Here again a corresponding reduction in nitrogen fixation is likely to occur. In such cases it may be possible, by the selection of a legume crop which is not so sensitive to acid soil conditions, to actually accumulate nitrogen more rapidly than would be possible if conditions favored rapid nitrification. The accumulation of nitrogen is not so important, however, as that it be usable and the conditions for crop growth are usually best satisfied when the nitrification and fixation processes are both rapid and properly balanced.

Judging from laboratory tests the most rapid combined fixation will occur under conditions in which the soil is kept neutral or slightly alkaline in reaction and in which the crop rotation has included regularly a legume crop which has been stimulated to large growth thru the use of phosphate and potash fertilizers. As the quantity of nitrogen in the soil increases a point will finally be reached at which the losses sustained equal the lessened rate of fixation due to the tendency of the nitrogen assimilating organisms to take the path of least resistance in their search for this element.

The division of nitrogen-fixation between the symbiotic and non-symbiotic groups cannot readily be estimated. The evidence indicates, however, that the non-symbiotic processes are responsible for a considerable part of the nitrogen fixed under field conditions. This does not mean that they are any more efficient but that they have the advantage of the time element since they are assumed to be more or less constantly at work while the legume organisms cannot function to best advantage except in the presence of their host. Apparently the *Azotobacter* are more seriously disturbed by acidity than most of the nodule organisms. Under these conditions their function may be taken over by certain nitrogen assimilating molds which find a favorable environment in acid soils.

Under what might be considered average cropping systems, the nitrogen gains and losses in the average soil in the latitude of Ohio apparently come to equilibrium at a nitrogen content of about 2,000 to 3,000 pounds per two million of surface soil. Fluctuations above or below this quantity are dependent largely upon the climate and upon the attention which the problem receives at the hand of the farmer. The use of phosphate and potash fertilizers apparently enable the nitrogen fixing organisms to satisfy the nitrogen requirements of larger crop yields, but if the crops are removed the point of equilibrium in the soil is disturbed but little. If there is an accumulation of phosphorus either as a result of its application or

for any other reason, the point of equilibrium will be raised to correspond to the increased content of this element. The only correlations with the nitrogen content which have been established are those of the content of phosphorus and of organic matter in soils of the same type and under similar climatic and cultural conditions.

LITERATURE CITED.

1. AMES, J. W. Supply of nitrogen in the soil. Ohio Agr. Exp. Sta. Mo. Bul., v. 5, p. 174–178, 1920.
2. AMES, J. W., BOLTZ, G. E., and STENIUS, J. A. Effect of fertilizers on the physical and chemical properties of wheat. Ohio Agr. Exp. Sta. Bul. 243, p. 585, 1921.
3. ARNY, A. C., and THATCHER, R. W. The effect of different methods of inoculation on the yield and protein content of alfalfa and sweet clover. *In* Jour. Amer. Soc. Agron., v. 9, p. 135–136, 1917.
4. ASHBY, S. F. Some observations on the assimilation of atmospheric nitrogen by a free-living soil organsim, *Azotobacter chroococcum*, by Beyerinck. *In* Jour. Agric. Sci., v. 2, p. 34–51, 1907.
5. BEAR, F. E. and MCCLURE, G. M. Sampling soil plots. *In* Soil Sci., v. 9, p. 65–75, 1920.
6. BEAR, F. E. and SALTER, R. M. The residual effects of fertilizers. West Va. Agr. Exp. Sta. Bul. 160, p. 18, 1916.
7. BONAZZI, A. Studies on *Azotobacter chroococcum* Beij. *In* Jour. Bact., v. 6, p. 331–369, 1921.
8. CLARKE, F. W. Data of geological chemistry, U. S. G. S. Bul. 616, p. 78, 1916.
9. COLLISON, S. E. and WALKER, S. S. Losses of fertilizers by leaching. Fla. Agr. Exp. Sta. Bul. 132, p. 10–13, 1916.
10. DOLE, R. B. and STABLER, H. Water Supply Paper No. 234 U. S. G. S. p. 78, 1909.
11. DYER, B. Results of investigations on the Rothamsted soils. U. S. D. A. Off. Exp. Sta. Bu. 106, 1902.
12. FRED, E. B. The fixation of atmospheric nitrogen by inoculated soybeans. *In* Soil Sci., v. 11, p. 470, 1921.
13. ———. Assimilation of nitrogen by different strains of *B. radicicola* in the absence of the host plant. *In* Ann. Rep. Vir. Agr. Exp. Sta. p. 132–134, 1908.
14. FRED, E. B. and DAVENPORT, AUBREY. Influence of reaction on nitrogen assimilating bacteria. *In* Jour. Agric. Res., v. 14, p. 331, 1918.
15. GOLDING, JOHN. Importance of removal of products of growth in assimilation of nitrogen by organisms of the root nodules of leguminous plants. *In* Jour. Agric., Sci., v. 1, p. 59, 1905.
16. HALL, A. D. On the accumulation of fertility by land allowed to run wild. *In* Jour. Agr. Sci., v. 1, p. 241–249, 1905.
17. ———. The Book of the Rothamsted Experiments, Dutton and Co., p. 235, 1917.
18. HARTWELL, B. L. and PEMBER, F. R. The gain in nitrogen during a five-year pot experiment with different legumes. R. I. Agr. Exp. Sta. Bul. 147, p. 14, 1911.

19. HENRY, W. A. and MORRISON, F. B. Feeds and Feeding. The Henry Morrison Co., Madison, Wis., p. 661, 1915.
20. HILTNER, L. Stickstoffmehrer and stickstoffzehrer. *In* Lafar Handbuch der Technischen Mykologie. Jena. p. 24, 1906.
21. HOPKINS, G. G. Soil Fertility and Permanent Agriculture. Ginn and Co., Boston. p. 217, 1910.
22. LAWES, J. B., and GILBERT, J. H. On the sources of nitrogen of vegetation. *Abs. in* Proc. Roy. Soc. Lond., v. 10, p. 544, 1860.
23. LIPMAN, J. G. Micro-organisms as a factor in soil fertility. Marshall's Micro-biology, Blakiston's Sons and Co., Philadelphia. p. 343, 1917.
24. LIPMAN, J. G. and BLAIR, A. W. Nitrogen losses under intensive cropping. *In* Soil Sci., v. 12, p. 1–21, 1921.
25. LYON, T. L. Influence of higher plants on bacterial activities in soils. *In* Jour. Amer. Soc. Agron., v. 10, p. 313–322, 1919.
26. LYON, T. L. and BIZZELL, J. A. Some relations of certain higher plants to the formation of nitrates in soils. Cornell Agr. Exp. Sta. Mem. 1, p. 111, 1913.
27. ———. Lysimeter Experiments. Cornell Agr. Exp. Sta. Mem. 12, p. 36, 1918.
28. MILLER, M. F. and HUDELSON, R.R. Thirty years of field experiments with crop rotation, manure, and fertilizers. Mo. Agr. Exp. Sta. Bul. 182, p. 20, 1921.
29. RUSSELL, E. J. Letter from Rothamsted Agr. Exp. Sta. Oct. 4, 1921.
30. RUSSELL, E. J. and RICHARDS, E. H. The amount and composition of rain falling at Rothamsted. *In* Jour. Agric. Sci., v. 9, p. 309–338, 1919.
31. SWANSON, C. O. The effect of prolonged growing of alfalfa on the nitrogen content of the soil. *In* Jour. Amer. Soc. Agron., v. 9, p. 305–315, 1917.
32. WHITE, J. W. Letter from Pa. Agr. Exp. Sta. Oct. 4, 1921.
33. WILFARTH. Uber stickstoffaufnahme der pflanzen. *In* Land. Vers. Stat v. 34, p. 460–61, 1887.
34. WILSON, B. D. Nitrogen in the rainwater at Ithaca, New York. *In* Soil Sci., v. 11, p. 101–111, 1921.
35. WRIGHT, R. C. Nitrogen relations of certain crop plants when grown alone and in association. *In* Jour. Amer. Soc. Agron., v. 11, p. 49–67, 1919.

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THE EFFECT OF FERTILIZERS ON YIELD AND MARKET CONDITION OF CORN.[1]

W. B. ELLETT AND T. K. WOLFE.[2]

In the application of fertilizers to the soil the primary object is usually to increase the yield of the crops. However, in some instances the fertilizers applied noticeably affect the crops in other ways than in increasing yield. These effects are usually classed as secondary; but they very often play an important role in crop production. It has been shown that certain plant nutrients decrease the winter-killing and Hessian fly injury to wheat. In the case of corn some fertilizers hasten maturity, increase the percentage of marketable grain, and the proportion of grain to cob.

The data presented in this paper were secured from a four year rotation experiment, from a continuous cropping experiment with corn, and from a green manuring experiment. Various fertilizers have been applied as shown in the tables. The soil on which the experiments were conducted is a Hagerstown silt loam. The acid phosphate used was the commercial goods guaranteed to contain 16 percent available phosphoric acid. However, analyses were made each year of all commercial fertilizers used.

The rotation experiment was begun in 1909 and consisted of corn, wheat, and clover and grasses two years. Each year all four crops were grown. The materials were applied annually unless otherwise stated. The data secured from this experiment are presented in Table 1.

It is shown in Table 1 that phosphates and manure have increased the yield of grain. In case of commercial fertilizers lacking phos-

[1] Contribution from the Virginia Agricultural Experiment Station, Blacksburg, Va. Received for publication, November 4, 1921.

[2] Chemist and Associate Agronomist, respectively.

TABLE 1.— *The effect of fertilizers on the yield and marketable grain of corn in rotation, for the years 1915 to 1920, inclusive.*

Fertilizer applications per acre.	Results compared in bushels per acre. Average yearly yield.	Increase over check.	Marketable grain. Average percent.	Increase over check
Acid phosphate, 438 pounds	50.33	13.56	77.60	11.10
Dried blood, 308 pounds; Acid phosphate, 438 pounds; Muriate of potash, 100 pounds	59.09	22.32	83.19	16.69
Acid phosphate, 438 pounds; Muriate of potash, 100 pounds	52.65	15.88	82.30	15.80
Muriate of potash, 100 pounds	38.39	1.62	70.52	4.02
Dried blood, 308 pounds; Muriate of potash, 100 pounds	40.32	3.55	65.75	—.75
Dried blood, 308 pounds; Acid phosphate, 438 pounds	44.17	7.40	71.24	4.74
Dried blood, 308 pounds	32.80	—3.97	61.16	5.34
Manure, 16 tons before corn	63.00	26.23	80.18	13.68
Manure, 4 tons annually	65.49	28.72	83.43	16.93
Manure, 16 tons before corn; Acid phosphate, 438 pounds annually	70.91	34.14	83.36	16.86
Floats, 218 pounds	40.46	3.69	68.08	1.58
Check	36.77	......	66.50	......

phoric acid, the increase in yield has been small and there was actually a decrease when dried blood has been used alone. It can be seen also that acid phosphate has given a larger increase than has floats or ground phosphate rock. It seems that organic matter and phosphates are the chief limiting factors of production under the conditions of these experiments. There were two checks used in the test and the difference in yield was 4.43 ± 6.18 bushels.

In case of marketable grain, as well as with yield, the materials which has given the most marked results are soluble phosphates and stable manure. The difference in the checks in regard to the marketability of grain was 10.13 ± 5.48 percent.

The value of soluble phosphates in hastening the maturity of corn has been shown by Brooks (1).[3] Hall (4), quoting from the work of Sir John Lawes, states that phosphoric acid stimulated root growth and the propensity of plants to tiller. Grantham (3) emphasizes the value of phosphoric acid in increasing the tendency of wheat to tiller and the effect of tillering on the yield of the plant. Wolfe (5) has found that phosphates, lime and stable manure increase not only the yield but the percentages of marketable grain, grain to cob, and matured ears of corn when the crop was grown in rotation and under continuous cropping conditions. It seems that the right proportion of nitrogen, phosphorous and potassium is more important

[3] Reference by numbers is to "Literature cited." p. 158.

in regard to maturity and growth than is any single element. Ellett and Wolfe (2) found acid phosphate and stable manure to be effective in increasing yield of wheat by lessening the injury from winter-killing and the Hessian fly.

The continuous cropping experimental plots were started in 1908 and have been planted to corn each year since that time. The applications of the different materials were made annually in the spring. The results in regard to yield and percentage of marketable grain are presented in Table 2.

TABLE 2.— *The effect of fertilizers on the yield and marketable grain of corn under continuous cropping, for the years 1915 to 1920, inclusive.*

Treatment.	Results compared in bushels per acre. Average yearly yield.	Increase over check.	Marketable grain. Average percent.	Increase over check.
Acid phosphate, 600 pounds	29.66	16.91	67.93	37.38
Acid phosphate, 200 pounds	27.38	14.63	62.72	32.17
Floats, 99.6 pounds	25.64	12.89	62.81	32.17
Thomas slag, 192 pounds	22.19	9.44	62.26	31.71
Nitrate of soda, 100 pounds; Acid phosphate, 200 pounds	28.87	16.12	62.24	31.69
Acid phosphate, 200 pounds; Sulphate of potash, 50 pounds	23.61	10.86	58.97	28.42
Nitrate of soda, 100 pounds; Sulphate of potash, 50 pounds	14.78	2.03	43.04	12.49
Check	12.75	......	30.55	......
Manure, 10 tons	53.41	31.24	80.83	24.56
Manure, 10 tons; Burnt lime, 1,200 pounds	57.09	34.92	80.17	23.90
Burnt lime, 1,200 pounds	43.04	20.87	70.11	13.84
Nitrate of soda, 100 pounds	21.13	—1.04	56.39	.12
Nitrate of soda, 100 pounds; Acid phosphate, 200 pounds; Sulphate of potash, 50 pounds	41.65	19.48	65.14	8.87
Check	22.17	......	56.27	......

The results secured from the use of 200 pounds of acid phosphate to the acre have been about equal to those secured from the use of 600 pounds of this material. If the data are considered as a whole, it seems that 200 pounds of acid phosphate to the acre is about the proper amount for corn under the conditions of the experiment, from the standpoint of profit. In the continuous cropping experiment, floats or ground phosphate rock, Thomas slag, and acid phosphate gave practically equivalent results when the materials were applied so as to supply amounts of phosphoric acid equal to that in 200 pounds of acid phosphate.

The results of Table 2 indicate that phosphate, lime, and manure are important in increasing the yield and the percentage of marketable

grain in case of corn. When commercial fertilizers have been used without phosphate both the yield and percentage of marketable grain is lower.

If the results secured from the use of the complete fertilizer and from the stable manure are compared, it will be found in the continuous cropping test, that the stable manure has given both higher yield and higher percentage of marketable grain than has the complete fertilizer. The former material supplies annually approximately 120 pounds each of nitrogen and potash and about 60 pounds of phosphoric acid. The complete fertilizer furnishes annually 16 pounds nitrogen, 32 pounds of phosphoric acid, and 25 pounds of potash; manifestly the stable manure supplied much larger quantities of these plant nutrients. Thus, the stable manure and the complete fertilizer results are not strictly comparable. It is difficult to estimate the proportion of the increase that should be attributed to the organic matter and the part to the additional plant nutrients in the stable manure.

In the rotation experiment, the complete fertilizer and stable manure, four tons annually, gave practically the same percentage of marketable grain, but the latter produced the higher yield. In the complete fertilizer, there was supplied 40 pounds of nitrogen, 70 pounds of phosphoric acid, and 50 pounds of potash. The stable manure supplied approximately 48 pounds each of nitrogen and potash and 24 pounds of phosphoric acid. These figures show that the stable manure and complete fertilizer added practically the same quantities of nitrogen and potash, but the former supplied only one third as much phosphoric acid. However, the data in Table 1 show that the average yield of the manured plot surpassed that of the complete fertilizer plot by 6.4 bushels. The percentage of marketable grain produced was approximately the same from the two treatments. Such results would indicate that the difference in yield may be attributed to the effect of the organic matter in the stable manure. It would also appear that applications of acid phosphate as heavy as made in this experiment are not necessary from the standpoint of remunerative returns. When acid phosphate was added to a 16 ton application of manure the yield was increased by 7.91 bushels, as compared with 16 tons of manure alone; while the marketable grain was increased only 3.18 percent. The application of stable manure and acid phosphate gave an increase in yield of 11.82 bushels greater than the complete fertilizer, while the percentage of marketable grain from the two treatments were practically the same. The increase in yield from the 16 tons of

stable manure and acid phosphate, as compared with the complete fertilizer, is about twice that of the four tons of stable manure annually when the latter is compared with the complete fertilizer treatment. However, the amount of phosphoric acid applied in the stable manure and phosphate treatment is about seven times that supplied by the four tons of stable manure annually. Thus, it is evident that the increased yield from the former treatment is not profitable. This is to be expected if the law of diminishing returns is followed.

The effect of green manuring on the yield and percentage of marketable corn is shown in Table 3. This experiment was started in 1917 and includes three one-tenth acre plats. Corn was grown each year on plats to which were applied acid phosphate at the rate of 400 pounds to the acre. On two of the plats a mixture of winter vetch and crimson clover was seeded at the last cultivation of the corn. The third plat was left bare through the winter and serves as a check plat. The crop on one of the plats was cut each year, while the crop on the other crimson clover-vetch plat was turned under. The winters of 1917 and 1920 were very severe and the crops were failures. Hence, there was nothing to be turned under in the following springs. The total amount of crops in the form of field cured hay removed the other two years was 838 pounds. This is equivalent to about 3500 pounds of green material. The data secured are presented in Table 3.

TABLE 3.— *The effect of green manuring on the yield and marketable grain of corn, for the years 1917 to 1920, inclusive.*

	Results compared in bushels per acre.		Marketable grain.	
Treatment.	Average yearly yield.	Increase over check.	Average percent.	Increase over check.
Crimson clover and vetch cut off. .	42.67	—.41	83.56	—.14
Crimson clover and vetch turned under.	48.74	5.66	86.46	2.76
Check.	43.08	. . . . . .	83.70	. . . . . .

The results shown in Table 3 indicate that the green manuring crop has had but little effect on the percentage of marketable grain. The effect on yield is more pronounced. It is interesting to observe that from the plats where the crops of vetch and crimson clover have been removed the yield and quality of corn has been maintained. In the rotation experiment, Table 1, it appears that the organic matter of the stable manure increased the yield of grain, but had little effect on the percentage of marketable grain as compared

with complete fertilizers treatment. This apparent effect of organic matter in the stable manure is substantiated by the results obtained with green manure as shown in Table 3. The green manuring crop has returned to the soil no plant nutrients, other than nitrogen, except those secured from the soil. Thus, a larger amount of the increase in yield from a green manuring crop can be directly attributed to the effect of organic matter than when stable manure is used. In the latter material the plant nutrients introduce complicating factors.

The results indicate strikingly that the materials which increase the yield of corn are also those which increase the percentage of marketable grain. These materials are phosphates and stable manure. These same materials have previously (2) been found to increase the yield of wheat and to reduce the injury from winterkilling and the Hessian fly. The soils of Virginia seem in many instances, to be markedly poor in phosphorus and organic matter as indicated by the increase in production of crops when these materials are applied.

Thus, it seems that the materials needed to increase yield are also the ones which will improve the quality of the corn crop.

In conclusion, the results of these experiments seem to indicate, under the conditions which prevailed, that phosphates and stable manure are the most valuable materials used for increasing the yield and quality of the corn crop.

Organic matter, in the form of green manure as well as in the form of stable manure, has been valuable in increasing yield.

LITERATURE CITED.

1. Brooks, Wm. P. Phosphates in Massachusetts agriculture; importance, selection and use. Mass. Agr. Expt. Sta. Bul. 162, 1915.
2. Ellett, W. B., and Wolfe, T. K. The relation of fertilizers to Hessian fly injury and winterkilling of wheat. *In* Jour. Amer. Soc. Agron., v. 13, no. 1, p. 12–14, 1921.
3. Grantham, A. E. The tillering of winter wheat. Del. Agr. Expt. Sta. Bul. 117, 1917.
4. Hall, A. D. Fertilizers and manures, p. 139, E. P. Dutton and Co., New York, 1910.
5. Wolfe, T. K. Comparative value of phosphate carriers. Commercial Fertilizer, p. 43–47, Walter W. Brown, Atlanta, 1919.

THE NITROGEN INVENTORY AS AFFECTED BY LIVESTOCK VS. GRAIN FARMING.[1]

C. G. Williams.[2]

In 1910 the Ohio Station began an experiment of comparing livestock with grain farming on the silt loam soil of Wooster, Ohio. The rotation followed is corn, soybeans, wheat and clover. In the livestock system, all the crops grown except wheat are either fed to livestock, or passed into the manure as bedding, and the manure made from the four crops is applied to the succeeding corn crop.

In the grain farming the corn, soybeans and wheat are removed and sold; the stover and straw are left upon, or returned to, the land; and the clover is not harvested but allowed to stand until plowed under the following spring. No livestock is fed in the grain farming system.

Each tract receives two tons of ground limestone and 700 pounds of 16 per cent acid phosphate per acre, per rotation.

THE CROP YIELDS.

It will perhaps be of interest to note the average yield of crops under the two systems.

Eleven crops of corn have been harvested, with the following average yields: In the livestock system 67.90 bushels per acre: in the grain farming 61.18 bushels per acre; a gain of 6.72 bushels in favor of the livestock farming. The average yield of stover in the livestock system has been 3,100 pounds per acre. The stover has not been harvested in the grain farming but may be estimated at 2,790 pounds.

The 10-year average yield of soybeans has been 21.04 bushels in the livestock, and 18.39 bushels in the grain farming. Of straw, 2,043 pounds in the livestock and 1,802 pounds in the grain farming — a gain of 2.65 bushels of beans and 241 pounds of straw in favor of the livestock farming.

The average yield of wheat has been 34.61 bushels in the livestock and 30.42 bushels in the grain farming. Of straw, 3,158 pounds in livestock and 2,617 pounds in the grain farming — a gain of 4.19 bushels of wheat and 541 pounds of straw in favor of livestock farming.

[1] Paper read at the meeting of the Society held at New Orleans, La., November 7, 1921.

[2] Director, Agricultural Experiment Station, Wooster, Ohio.

The average yield of clover in the livestock farming has been 2.23 tons per acre. As the clover is not harvested in the grain farming, the yield can only be estimated. If it bears the same relation to the livestock yield as in the other crops of the rotation it has yielded 1.95 tons per acre, or a difference of 560 pounds per acre in favor of the livestock farming.

THE NITROGEN INVENTORY.

In view of the good applications of phosphorus and calcium carbonate in each system, it is perhaps fair to presume that the larger yields under the livestock system are due in the main to larger supplies of nitrogen available for crop production.

It may be of interest to compare the nitrogen intake and outgo in the two systems of farming with the actual nitrogen found in the soil as sampled and analyzed in July, 1921, 11 years after the experiment was started.

LIVESTOCK FARMING.

The loss of nitrogen per acre, per rotation in the crops grown in the livestock system is as follows:

Crop	Amount	Lbs. nitrogen
Corn	67.9 bu	66.92
Stover	3,100 lbs.	25.23
Wheat	34.61 bu	41.01
Straw	3,158 lbs.	16.67
Soybean crop	(⅓)	40.52
Clover crop	(⅓)	65.01
Total		255.36

The gain of nitrogen per acre, per rotation, in the livestock system is as follows:

	Lbs. nitrogen
14.46 tons of manure	217.48
Soybean roots and stubble	12.15
Clover, second growth and residues	97 51
Total	327.14

Net gain per acre, per rotation, 71.78 pounds of nitrogen.

GRAIN FARMING.

Similarly, the loss of nitrogen in the grain farming is as follows:

	Lbs. nitrogen
Corn (grain)	60.30
Wheat (grain)	36.05
Total	96.35

(The soybean residues amount to more than the nitrogen taken from the soil.)

The gain in nitrogen is as follows:

	Lbs. nitrogen
Soybean crop	11.16
Clover crop (2/3)	117.02
Total	128.18

Net gain per acre, per rotation, 31.83 pounds of nitrogen.

On the basis of these figures, some of which are only estimates, the livestock system leads the grain farming by 39.95 pounds of nitrogen per acre, per rotation.

As previously stated, nitrogen determinations were made in July, 1921, of each of the four sections in both systems, 40 borings being made for each sample with the following results:

Pounds of Nitrogen Per Acre (2,000,000 Pounds Soil)

Section.	Crop	Livestock system.	Grain system.
A	Corn	2,140	2,000
B	Clover	1,900	1,800
C	Wheat (stubble)	2,100	2,000
D	Soybeans	2,220	2,100
Average		2,090	1,975

Gain for livestock, 115 pounds of nitrogen per acre.

There has apparently been an accumulation of 115 pounds of total nitrogen more per acre in the livestock farming than in the grain farming, in addition to an average annual increase in crop production, which would call for 6.4 pounds of nitrogen per acre.

The balance in favor of livestock farming, as determined above, is 39.95 pounds per acre, per rotation, or an average annual balance of 9.99 pounds. If this balance could be accumulated for the 11-year period it would amount to 109.89 pounds, or within 5.11 pounds of the excess found in the soil

In conclusion: comparing the two systems of farming as conducted in the experiment in question, it appears that the livestock system results in slightly larger yields of crops year by year, and in a moderate increase in the nitrogen content of the soil.

AGRICULTURAL AND COMMERCIAL VALUES OF NITROGENOUS PLANT FOODS.[1]

A. W. BLAIR.[2]

By agricultural value, we may understand the value as measured by the increase in crop yields when results secured by different nitrogenous materials are compared with some one material taken as a standard. By commercial value, we would naturally understand the selling price of the different materials on a unit basis. One would suppose on first thought that commercial values would vary directly with the agricultural values. As a matter of fact, the situation may be just the opposite. If a nitrogenous raw material, or fertilizer, is high in price it does not necessarily follow that it will give high agricultural returns when compared with other materials.

It is highly desirable that such a relationship should exist, but there are certain reasons why it has not been so in the past, at least. A nitrogenous material may have a characteristic, or property, which is supposed to give it an advantage, or a disadvantage when compared with some other nitrogenous material.

To cite two examples: there was a time when some farmers believed that chemical salts like nitrate of soda had a stimulating effect which in the end was harmful to the soil. On the other hand, others have been inclined to assign an extra high value to organic nitrogenous materials on account of the organic matter which they supply, and also on the ground that they were believed to have more lasting effects than the soluble salts.

During the past quarter of a century the problem has been widely studied by both European and American investigators. These studies have thrown new light on the problem, and have cleared up a number of disputed points.

Nearly three quarters of a century of work at the Rothamsted experiment station has shown that chemical salts may be used

[1] Paper No. 87 of the Journal Series, New Jersey Agricultural Experiment Stations, Department of Soil Chemistry and Bacteriology; read at the meeting of the Society held at New Orleans, La., November 7, 1921.

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continuously without injury to the soil; it has also been shown that the increased yields thus secured result in increased crop residues which go a long way towards maintaining the supply of organic matter in the soil. It has also been shown by carefully planned experiments which cover a period of 25 to 30 years, that organic nitrogenous fertilizers do not have more lasting qualities, when considered from a broad viewpoint, than the more quickly available mineral materials.

It is the purpose of this paper to present in a brief way some of the results secured at the New Jersey experiment station, which have led to this latter conclusion. Field experiments in which different nitrogenous materials have been compared on one-twentieth-acre plots, have been carried on for 14 years, but since the last four years' results have not been fully tabulated, the results for the first ten years only will be given.

FIELD EXPERIMENTS — COMPARISON OF MINERAL AND ORGANIC SOURCES OF NITROGEN.

Three plots have received annual applications of mineral nitrogenous materials: that is, nitrate of soda, ammonium sulphate and calcium nitrate; while three others have received organic nitrogenous fertilizers, that is, blood, fish and tankage. The materials have been applied in such amounts as to give the same amount of nitrogen to each plot. Lime, phosphoric acid and potash have been applied in liberal amounts.

A five-year rotation consisting of corn, oats (two years), wheat and timothy for the first five years and corn, oats, wheat and timothy (two years) for the second five years has been carried out.

The results for the 10 years are summarized in Table 1.

TABLE 1.—*A comparison of mineral and organic nitrogen in a 5-year field rotation.*

	Average yield of dry matter per acre.				Average yield of nitrogen per acre.	
	1908–1912.		1913–1917.			
Treatment.	Grain.	Straw, hay, etc.	Grain.	Straw, hay, etc.	1908–1912.	1913–1917.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Mineral nitrogen (Ave. plots 9, 10, 11)	1283	3163	848	2734	50.9	35.7
Organic nitrogen (Ave. plots 13, 14, 15)	1215	2519	812	2251	40.3	32.3

From this it will be noted that, in every case, the mineral materials gave larger yields and larger nitrogen returns than the organic

materials. The differences are not great, but certainly they are sufficient to show that the organic materials do not have greater lasting properties than the mineral materials.

In a comparison of nitrate of soda with fish and tankage in growing potatoes on a heavy loam soil, using 1,600 pounds of a 4 (NH_3) — 8 (P_2O_5) — 3 (K_2O) fertilizer per acre, the five-year average yields (all grades) are as follows:

All nitrogen from nitrate	251 bu. per acre
All nitrogen from fish	244 bu. per acre
All nitrogen from tankage	241 bu. per acre

In the same five-year test, when one-half the nitrogen was taken from nitrate of soda and one-half from ammonium sulphate, the average yield was 253.4 bushels per acre, and when half was taken from nitrate and half from either fish or tankage the yield was about 257 bushels per acre.

It will be noted that when nitrogen was obtained from two sources the yields were from two to 16 bushels higher than when a single source was used, but the yields with the best two-source mixture were only six bushels more than the yield with all the nitrogen coming from nitrate of soda, and only about three and one-half bushels more than the yield with the nitrogen coming from sodium nitrate and ammonium sulphate, half and half. But the introduction of two percent of organic nitrogen added very materially to the cost of the fertilizer.

CYLINDER EXPERIMENTS — GREEN MANURE AGAINST STABLE MANURE.

During a period of 13 years, 1907–1919, inclusive, a comparison has been made between nitrogen from stable manure used at the rate of 15 tons per acre once in two years and nitrogen gained through the growing of legumes, these being grown as a green manure crop without interfering with the main rotation.

The work has been carried out in cylinders under natural weather conditions, by using a four-crop rotation consisting of rye, corn, potatoes and oats, the four crops being grown every year, and the work repeated on eight types of soil. Lime, phosphoric acid and potash were added in liberal amounts. Corn was harvested as forage and the other crops grown to maturity.

The average yield of dry matter for the four crops (four cylinders) on the eight types of soil for the 13 years was 749 grams or 187¼ grams per cylinder, for the green manure, and 542 grams or 135½ grams per cylinder for the stable manure. This is an increase for the green manure over the stable manure of 38 percent.

It is impossible to give an exact accounting of the cost of the two methods of furnishing nitrogen, but a fair approximation may be made. A fair estimate for the cost of the manure for the period covered would be $3.00 per ton. This would make the average annual application (seven and one-half tons per acre) cost about $22.50. It is very difficult to arrive at a figure to represent the average cost of putting in a legume green manure, but it seems safe to say that this would not exceed $6.50 per acre. The green manure method would, therefore, result in a saving of $10.00 to $12.00 per acre over the stable manure after making due allowance for the phosphoric acid and potash in the manure, in addition to the larger yields with the former.

In the meantime, the soil in the green manure cylinders has been kept on a level with, and in some cases on a higher plane as to nitrogen content, than the soil of the stable manure cylinders.

CYLINDER EXPERIMENTS — NITRATE OF SODA COMPARED WITH DRIED BLOOD.

For a period of 20 years, nitrate of soda and dried blood have been compared in cylinder experiments on a loam soil in a five-year rotation of corn, oats (two years), wheat and timothy. Lime, phosphoric acid and potash have been supplied in liberal amounts, so that a deficiency of these should not become a limiting factor. The average yields of dry matter, in grams per cylinder, and the percentage of nitrogen recovered have been as follows:

	Dry matter — grams.		Percentage, nitrogen recovered.
	First 10 years.	Second 10 years.	
Nitrate of soda	237	243	62.4
Dried blood	207	185	38.7

In the case of the nitrate of soda it will be noted that the yield for the second 10-year period is greater than for the first, while with blood the reverse is true. The difference in the amount of nitrogen recovered is greatly in favor of the nitrate of soda.

CYLINDER EXPERIMENTS — NITRATE OF SODA COMPARED WITH DRIED BLOOD IN A 50 % SAND AND LOAM-SOIL MIXTURE.

During a period of nine years, nitrate of soda and dried blood have been compared as sources of nitrogen on a soil mixture, 50 percent of which is coarse white sand. As in the other cases, lime, phosphoric acid and potash have been supplied in liberal amounts. Two crops have been grown each year, barley as the main crop, followed by buckwheat as a residual crop (Japanese millet one year); but the fertilizers were always applied for the barley.

The average yields of dry matter in grams per cylinder and the percentage of nitrogen recovered have been as follows:

	Dry matter—grams.	Percentage, of nitrogen recovered.
Nitrate of soda	152.1	58.2
Dried blood	126.8	40.4

Of the applied nitrate nitrogen, 58.2 percent was recovered; and of the blood nitrogen, 40.4 percent; a difference in favor of the nitrate of nearly 18 percent.

These cylinders were open at the bottom and exposed to natural weather conditions so that leaching due to the rainfall was not hindered in any way. Therefore, with the yield of dry matter and the nitrogen recovery both decidedly in favor of the nitrate nitrogen, over a period of nine years and with a soil 50 per cent of which is coarse white sand, there seems little reason for saying that the loss of nitrate nitrogen through leaching is greater than the loss of organic nitrogen from the same cause. If it were so, how could the crop yields be maintained over so long a period of years? It could hardly be an accident that in all these cases and during all these years the nitrate nitrogen gave larger yields than the organic nitrogen. There must be some virtue in the nitrate which the organic material does not possess.

For the present we may pass over the reason for this difference, since here we are concerned primarily with what has actually happened or the relative effect of the two materials.

COMMERCIAL VALUES.

But the difference in yield is not the only question to be considered. Since 1903, nitrogen in the form of organic material has been sold at a higher price per unit than nitrogen in the form of nitrate of soda and sulfate of ammonia. However, it is not necessary to point out here how great the differences in price have been. It is enough that nitrogen in the organic materials has cost the farmer more than nitrate and ammonia nitrogen. At the same time in our experiments it has given no greater returns, and indeed in the majority of cases has given lower returns.

A period of 20 years is certainly long enough to give a fair test of the residual effects of such materials, and it would therefore seem that we are not longer justified in saying that the organic nitrogenous materials have greater "staying" qualities than the soluble forms.

The loss of nitrate nitrogen on account of leaching must be considerable, otherwise the recovery would be much higher than these and other experiments have shown it to be (about 62 percent under most favorable conditions), but certainly it is not greater, under average conditions, than the loss from organic materials.

It would appear that the crop's ability to use the readily available nitrate early in its growth, and thus get an early and vigorous start, has much to do with the larger yields where nitrate was used.

In conclusion it may be said that the aim of this paper is not to discourage the use of farm manures or organic nitrogenous materials, but rather to insist that their commercial values be made more in keeping with their agricultural values as shown by long time vegetation tests.

A STUDY OF PRESENT AND FUTURE SUPPLIES OF FERTILIZER NITROGEN.[1]

S. B. Haskell.[2]

Adequate data showing present consumption of fertilizer nitrogen are not available. The best information lies in the reports made by the different components of the fertilizer industry, during the war, to the fertilizer administrator. At that time these reports were required. It is true that business conditions during the war were so abnormal as to raise a question as to the value of statistics accumulated during that period. The same thing, however, may be said of the three years which have elapsed since the close of the war. Therefore, rightly or wrongly, I have taken the year 1918 as a basis for estimating the consumption of fertilizer nitrogen. In all probability the consumption during the present year is less than that indicated in the following table:

CONSUMPTION OF FERTILIZER NITROGEN, 1918.

Of the various methods of classification which may be used in studying the above table of consumption, one of the most significant is on the basis of origin, whether essentially a by-product in nature or otherwise. Classified in this way 64 percent of the fertilizer nitrogen used in the country in 1918 was a secondary product, 36 percent a primary product. The figures show how far removed is the fertilizer industry today from its original and primary function as a scavenger industry.

[1] Paper read at the meeting of the Society held at New Orleans, La., November 8, 1921.

[2] Director, Agricultural Experiment Station, Amherst, Massachusetts.

TABLE 1.— *Estimated consumption of fertilizer ammonia in 1918.*

Product.	Total tonnage.	Estimated use in fertilizers. Percent.	Estimated use in fertilizers. Tonnage.	Nitrogen percent.	Pounds of nitrogen used for fertilizer.	Units of ammonia (1 unit = 16.47 lbs. nitrogen.)
Packing Industry						
Tankage, high-grade	[1] 211,329	[2] 56.9	120,246	[4] 9.0	21,644,280	1,314,164
Tankage, low-grade	[1] 59,604	[2] 89.5	53,346	[4] 5.2	5,547,984	336,854
Dried blood	[1] 35,463	[2] 83.6	29,647	[4] 11.4	6,759,516	410,414
Hair	[1] 8,754	[2] 41.8	3,659	[4] 15.0	1,097,700	66,648
Hoofs and horns	[1] 4,671	[2] 88.3	4,124	[3] 12.5	1,031,000	62,599
Raw bones	[1] 33,644	[2] 82.6	27,790	[1] 2.5	1,389,500	84,366
Dried bones	[1] 21,475	[2] 85.5	18,361	[1] 4.5	1,652,490	100,333
Concentrated tankage	[2] 25,490	[2] 63.4	16,161	[5] 11.2	3,620,064	219,797
Municipal Waste						
Garbage tankage	[2] 34,718	[2] 100.0	34,718	[4] 2.7	1,874,772	113,830
Fish Industry						
Dried scrap	[1] 53,028	......	[4] 28,813	[4] 7.4	4,264,324	258,916
Acidulated scrap	....	......	[4] 24,215	[4] 5.0	2,421,500	147,026
Vegetable Ammoniates						
Cottonseed meal	[6] 1,616,617	......	[6] 507,186	[4] 6.9	69,991,668	4,249,656
Castor pomace	....	......	[4] 36,481	[4] 5.4	3,939,948	239,220
Miscellaneous						
Leather scrap	....	......	[4] 13,892	[4] 10.7	2,972,888	180,503
Natural guano	....	......	[4] 52,549	[4] 6.4	6,726,272	408,395
Base goods(?)	....	......	[4] 502,132	[4] 2.0	20,085,280	1,219,507
Miscellaneous	....	......	[4] 29,259	[4] 5.0	2,925,900	177,650
Total organic	....	......	1,502,579	....	157,945,086	9,589,878

TABLE I.—(*Continued*)

Inorganic						
Nitrate of soda	....	......	[4] 234,794 / [7] 78,265	[4] 15.5	97,048,290	5,892,428
Sulfate of ammonia	[8] 388,457	......	[4,9] 103,356	[4] 20.0	41,342,400	2,510,164
Ammonium phosphate	....	......	[4,10] 7,098	[4] 10.7	1,518,972	92,227
Cyanamid	....	......	[4,10] 6,099	[4] 12.8	1,561,344	94,799
Total inorganic	....	......	429,612	....	141,471,006	8,589,618
Total, organic and inorganic	....	......	1,932,191	....	299,416,092	18,179,496

References on basis of which estimates are made

[1] Am. Fert. Handbook, 1921, p. 50.
[2] U. S. D. A. Bul. 798, Table VII, p. 8.
[3] Average of maximum and minimum, Am. Fert. Handbook, 1921, Table IV, p. 50.
[4] U. S. D. A. Bul. 798, Table VI, p. 7.
[5] "Compilation of Analyses." Mass. Agr. Expt. Sta.
[6] U. S. D. A. Bul. 798, Table VIII.
[7] Estimated use in direct, unmixed form.
[8] Am. Fert. Handbook, 1921, p. 96.
[9] Does not include that applied in unmixed form.
[10] Below normal — probably of no significance.

A second significant classification has to do with domestic *versus* foreign origin. The only material in the whole list which is now imported in quantity is nitrate of soda. Previous to the war, sulfate of ammonia was likewise imported; but at the present time these importations are practically nil. Cyanamid comes from Canada; but to all intents and purposes this is domestic production. In 1918, 32 percent of our nitrogen was imported, 68 percent produced in America.

Theoretically all of the nitrogen produced in the country, particularly by-product nitrogen, should be used before making importations to complete the available supply. This statement, however, cannot be made in dogmatic form, because nitrate of soda as a source of nitrogen has certain properties not found in other materials. It may be a better carrier under some conditions, or a poorer carrier under other conditions. It is this essential difference between the crop-producing values of the several carriers of nitrogen which makes probable some importations of nitrate, almost without regard to the supplies of domestic nitrogen available for use.

But in order to get a true picture of the conditions of our nitrogen supply, it is necessary to go a step further and discuss the domestic nitrogen in terms of primary and secondary products. 95 percent of the total domestic nitrogen is of by-product nature, with but 5 percent ranking as a primary product. This classification is exceedingly important, since one of the economic functions of the fertilizer industry is to furnish a market for the waste products of a number of other industries. Any governmental policy having to do with the nitrogen supply, which fails to consider this relationship of the fertilizer industry to other industries, is certain to cause difficulties of an economic nature.

A final classification, and this time of agronomic significance, is that of form of nitrogen. Barring fruitless argument as to what constitutes organic or mineral nitrogen, it will be seen that approximately one-half of the total supply of fertilizer nitrogen is from organic sources. The remaining half is usually considered to be in inorganic form, despite the fact that cyanamid, chemically, is an organic product. Of this second half, roughly five-eighths is a primary mineral product, nitrate of soda. Sulfate of ammonia is a by-product of manufacture. Ammonium phosphate and cyanamid are primary manufactured products.

It is interesting to compare the 1918 consumption of nitrogen with that of 1913, five years previous. According to the report of the Federal Trade Commission, the consumption in the latter year totaled

16,859,874 units of ammonia. On this basis, the period from '13 to '18 saw an increase in consumption of fertilizer nitrogen of 7.8 percent. In all probability this figure is much lower than would have been the case had the 1918 supplies of fertilizer nitrogen been larger. The limitations during that year were in quantity and not in demand.

OUR FUTURE SUPPLIES.

To plot the consumption of fertilizer nitrogen for past periods of record is easy. To calculate the increase in consumption period by period is likewise easy, as is also the labor of carrying out the curve estimating probable consumption in any year in the future. The real need for fertilizer nitrogen, however, is a function of population density and standard of living. The actual utilization of this nitrogen is dependent on the ratio between its cost and prices received by farmers for crops. The fulfillment of any prophecy regarding consumption is so dependent on world-wide conditions as to make such prophecy of doubtful value. The tariff policy of the United States will have a direct effect on the amount used. Should this policy handicap American producers in finding an export market, the total production of farm crops in this country will be less than would otherwise be needed — hence a slowing up in demand for fertilizer nitrogen. The labor policy, taxation policy, transportation conditions,—all of these have influence on a problem which is basically economic. Therefore, in place of estimating the future supply I must content myself with saying a few words on the limitations of each source of supply.

THE BY-PRODUCT PACKING INDUSTRY.

According to a representative of the Armour Fertilizer Company (page 71, Federal Trade Commission Report on the Fertilizer Industry), the amounts of tankages and blood recovered per animal slaughtered in the large abattoirs of the country are as follows:

TABLE 2.— *Pounds of by-products per animal.*

	Tankage	Blood.	Concentrated tankage.
Cattle	12.	7.	6.
Calves	2.4	.75	1.2
Sheep	1.2	.5	.6
Swine	4.8	1.2	2.4

Applying these figures to the last year of record of the commercial slaughter in the United States, we have in sight the production of tankage equivalent to 223,415 tons; of blood, 89,054 tons; and of

concentrated tankage, 111,707 tons; supplying a total of 5,200,000 units of ammonia. As a matter of fact this production will never be attained. The only present-day effective utilization of by-products is in the plants of the large packing houses. Municipal abattoirs seemingly have not been so constructed as to admit of the utilization of by-products. There is a question whether the installation of by-product plants for a business relatively as small as that of municipal abattoirs can be profitably made.

As regards importations from the Argentine, I am not prepared to make statement. Data are too few to admit of a safe generalization. As regards the possibilities of increased production in this country, I cannot see how there can be any great increase in the livestock industry of this country. United States census figures show a marked decline in animal units per unit of population from 1890 to 1920. In the former year this ratio was 93, for 1910 it had decreased to 69, the 1920 figure indicates 65. These figures show that with increasing population, and correspondingly increasing need for fertilizer nitrogen, there will be a relatively decreasing supply of by-product materials of animal origin. Coupled with this is the probability that in response to economic tendencies there will be an increase in utilization of tankage as feeding material. Digester tankage has been defined as "any tankage that has been cooked in a tank with forty pounds live steam pressure; that has been promptly pressed and dried so that the tankage will not become sour; that does not contain hair, hoofs and other foreign material that are not generally accepted as desirable carriers of protein." According to the table presented above, slightly less than half of the high-grade tankage is now in use for feeding purposes, with but a small percentage of the low-grade tankage so used. There will always be fertilizer tankage made in slaughter houses; but the indications are that more and more of this material will be used as animal food. This is in accord with the dictates of sound economy. It means, however, that we must look elsewhere for sources of nitrogen having the properties usually ascribed to animal organic substances.

FISH BY-PRODUCTS.

The conclusion regarding the supply of fish waste as fertilizer material must be much the same as that for animal organic products in the packing houses. There can doubtless be increased conservation of these by-products; but when one remembers that many of the fish caught are dressed at sea, with the waste thrown overboard, and that the cost of recovery in small plants is very much greater than it is in large plants, a question is naturally raised as to whether the

future will see greater supplies than are available at present. The very least that can be said is that in the period from 1912 to 1920, the only period which is available for study, not only was there no increase in the supply of fish by-products, but there was apparently an actual decrease. Perhaps this may be summarized by saying that the only factor which will bring about increased supplies of fish waste as a source of nitrogen is high-priced nitrogen.

VEGETABLE AMMONIATES.

In 1918 cottonseed meal supplied slightly less than one-fourth of the entire supply of fertilizer nitrogen in the United States. The great bulk of this was, of course, used in the South, in the place where it was produced, with relatively small quantities going north to be used as tobacco fertilizer. Fundamentally, every pound of undamaged cottonseed meal which goes into fertilizer is partially wasted. It should be fed. If the campaign, favored by the United States Department of Agriculture and ably supported by the different states of the South, for a more vigorous live-stock industry in the South is successful, it is probable that increasing quantities of cottonseed meal will be consumed as animal feeds year after year in the South. Furthermore the continued development of the dairy industry in the North will likewise cause increased quantities to be consumed directly as feed. The tendency therefore in the future must be towards decreased supplies of this by-product to be used as fertilizer. Other vegetable ammoniates are scarcely a factor in the market, except locally. As far as can be seen, there is no probability of large increase.

MISCELLANEOUS ORGANIC PRODUCTS.

There are four other sources of nitrogen which have more than local importance, at least for purposes of discussion. These include (1) leather waste, wool waste, etc.; (2) garbage tankage; (3) peat; and (4) sewage.

The utilization of leather and wool waste was in years past held back through question of the value of these materials as carriers of nitrogenous plant foods. The use of acid and heat in processing these materials has largely removed this objection to their use. The future, however, holds no promise of any greatly increased supplies.

As far as garbage tankage is concerned, continued development is dependent on the possibility of profitable production of the main product of garbage extraction, namely, grease in its various forms. It is stated that the installation of local reduction plants so equipped as to render possible the final production of garbage tankage must

be confined to cities of not less than 100,000 inhabitants. On this basis, the total maximum supply which may be expected from this source in the cities lying east of the Great Plains will be approximately 1,500,000 tons of garbage annually, from which approximately 200,000 tons of tankage can be produced, supplying a grand total of not more than 675,000 units of ammonia. This maximum, however, will not be attained in the near future, if ever.

Another potential source is peat. Barring the possibility of developing a biological process whereby the nitrogen of peat may be made available as a food for plants, there is no great hope in the present outlook. In the dim and far distant future it may be used as a source of fuel gases, with ammonia as one of the more prominent of the by-products. The only thing which can hasten this development, however, is the coming of high-priced nitrogen. The need of the country today, however, is for low-cost fertilizer nitrogen. For the present, therefore, peat, and likewise sewage, may be dismissed from consideration as significant sources of this important plant food.

Apparently, as far as one can see, the fertilizer industry of tomorrow must depend more largely on inorganic nitrogen than it has in the past. This may necessitate changes in certain of the manufacturing processes in the making of fertilizer, and likewise changes in the field practice in the use of fertilizer. Unless nitrogenous sources develop entirely different from any known today, however, these changes will be forced through sheer inability to obtain sufficient supplies of nitrogen in organic form.

SULFATE OF AMMONIA.

Ammonium sulfate is at present our largest single source of domestic-produced nitrogen. The United States now produces a supply sufficient for home use, together with a rather material margin for export. Thus, in 1920, the production in round numbers was 500,000 tons, containing 12,143,291 units of ammonia, or sufficient to furnish two-thirds of the quantity of fertilizer nitrogen used by the entire country in 1918.

No official data are available showing exports for 1920. From May on, however, 66,714 tons were exported. For the first eight months in the current year, the export was 41,760 tons. Previous to 1919, however, very little was sent out of the country. It is interesting in this connection to note that the present production of sulfate of ammonia is equal to two and one-half times that which was produced before the war. The Muscle Shoals plant No. 2, or " Cyana-

mid Plant", has a rated capacity equal to 40 percent of the by-product coke industry. Later on the question will arise as to whether the country can consume this tremendous supply of a single source of ammonia.

As is well known, the supply of nitrogen in the bituminous coal deposits of the country is very great. As an average about 20 pounds of nitrogen are contained in every ton of bituminous coal mined; but in 1913 only one-fourth of the coal coked was in ovens equipped for by-product manufacture, producing as one among many products, sulfate of ammonia; while in 1920, 60 percent of the coal coked was in by-product ovens.

It is interesting in this connection to note the variation year after year in the production of coal coked in the bee-hive ovens, as compared to the approximately constant production of coke from by-product ovens. The following table shows this variation, and also indicates the relatively enormous increase in the production of sulfate of ammonia from by-product coke ovens. From 1910 to 1915 the increase was rather slow absolutely, although as large relatively as it is from 1915 to 1920. Should the production of ammonium sulfate continue to increase in the geometrical progression illustrated in the two half decades shown in the table, the amount would soon be so great as to stagger the imagination. Naturally nothing of this sort can be expected.

TABLE 3.— *Bituminous coal coked, 1910–1920.*[3]

	By-product coke		Bee-hive coke		
Year	Quantity (short tons)	Percentage of total	Quantity (short tons)	Percentage of total	Total
1910	7,138,734	17.12	34,570,076	82.88	41,708,810
1911	7,847,845	22.07	27,703,644	77.93	35,551,489
1912	11,115,164	25.27	32,868,435	74.73	43,983,599
1913	12,714,700	27.46	33,584,830	72.54	46,299,530
1914	11,219,943	32.47	23,335,971	67.53	34,555,914
1915	14,072,895	33.8	27,508,255	66.2	41,581,150
1916	19,069,361	35.0	35,464,224	65.0	54,533,585
1917	22,439,280	40.4	33,167,548	59.6	55,606,828
1918	25,997,580	46.0	30,480,792	54.0	56,478,372
1919	25,143,542	56.1	19,650,000	43.9	44,793,542
1920	30,908,000	60.0	20,980,000	40.0	51,880,000

The great bulk of the sulfate of ammonia produced in this country comes from the by-product coke oven. Few of our municipal gas plants produce ammonia as a by-product. This contrasts rather

[3] Years 1910–1914: From "Mineral Resources of the United States," 1914. Years 1915–1920: From "Mineral Resources of the United States in 1920" (Preliminary Summary).

strongly with German and English practice, in which such production is customary. There is a possibility that the limit of erection of by-product ovens has already been reached. Ovens of this kind must be operated continuously day and night, and cannot be shut down as may be dictated by fluctuations of the steel industry. On the other hand, the time may come when coke as a smokeless fuel must take the place now held by anthracite. Certainly, the waning supplies of anthracite coal give grounds for this supposition. Despite the enormous increase in the amount of coal now being coked in by-product ovens, the waste inherent in the consumption of bituminous coal in other ways is enormous. The end of possible production of ammonium sulfate has not nearly been reached.

ATMOSPHERIC NITROGEN.

Atmospheric nitrogen, as fixed in electro-chemical ways, is a primary product made possible through the commercial sale of power. Its cost depends first on the capital invested in the plant and machinery, and secondly on capitalization of power privileges, patent rights and the like. Up to date there is but one plant in the country furnishing any quantity of fixed nitrogen per year, this being that of the American Cyanamid Company with its plant at the Canadian side of the Niagara Falls. Its rated capacity is 72,000 tons annually, of which between 40,000 and 45,000 tons go into fertilizer, with the balance entering the manufacture of such products as cyanide, ammophos, etc. Running at full capacity, therefore, the plant of the American Cyanamid Company is now equipped to supply us with one-twenty-fifth of the 1918 consumption of fertilizer nitrogen.

To date cyanamid is the only product of the fixation of atmospheric nitrogen which gives great promise commercially. The basic reason for this lies in economical utilization of power. According to C. G. Gilbert (Smithsonian Institute Special Bulletin, 1916),

> "The arc method of nitrogen fixation requires from 2.75 to 3 horse power years of electric power per ton of nitric acid yield. The cyanamid process, on the other hand, carried through only to the nitric acid stage, has a power cost of approximately one-half horse power year per ton of nitric acid. The labor costs in the two competing methods are practically equal. The raw material cost may be somewhat greater by the cyanamid method, but not enough larger to counterbalance the very great advantage in cost of power under which it operates."

The final product, however, is in a form which may best be utilized through mixing with other materials. Attempts at the direct application of the product have not been satisfactory. There is a question as to how much more of this material can be utilized directly on American farms.

In addition to the plant of the American Cyanamid Company, we have the great plant at Muscle Shoals, of which unit No. 2 is equipped for the manufacture of cyanamid. Should Congress authorize the use of the Muscle Shoals plant No. 2, it is estimated that by 1924 approximately 45,000 tons of nitrogen can be produced, gradually increasing to 55,000 tons by 1934. This would be equivalent to 6,678,810 units of ammonia, or one-third of the 1918 consumption of fertilizer nitrogen.

Whether the Haber process or any method of commercial nitrogen fixation other than the cyanamid process can be economically utilized, is a question which cannot now be answered. Data are too few and too untrustworthy to admit of answer.

NITRATE OF SODA.

The consideration of nitrate of soda has purposely been postponed until the last, on the somewhat erroneous supposition that all domestic-produced by-product materials would be utilized previous to importing a primary mineral product from abroad. That this assumption will not always hold has already been shown. Practically, however, we may look to nitrate of soda to balance any deficit between domestic production and desired consumption. As to the future supplies, no estimate is presented. Surveys have always been incomplete and more or less unreliable. Reports indicate that year after year lower grades of caliche have been mined. This indicates probably increased efficiency in manufacture rather than approaching depletion of the deposits. Along with this change in quality of the crude mineral, however, has come an increasing overhead tax imposed by the Chilean government. It is difficult to measure the absolute amount of this tax, because of the fluctuations, almost daily fluctuations in fact, in exchange. Gilbert estimates it at approximately $11 per long ton. Probably the most that can be said today is that there is no present evidence of serious depletion of nitrate supplies.

THE ECONOMIC ASPECTS OF THE PROBLEM.

The production of fertilizer nitrogen is economic only when the product may be economically used. To find its largest usefulness the product must be offered at a price which will admit of clear recognition of profit. Just so long as the matter of profit is a subject of fruitless argument, will the use of nitrogen tend to be retarded. The extension of the use of this plant food should come through the competition of product for a market rather than through the competition of the market for the product. The one leads to low prices and economical business administration, the other to high prices

with attendant extravagant and wasteful business administration. With conditions as they are today, not modified by government interference in industry, the commodity competes for the market. Secondary, or by-product nitrogen, competes with primary nitrogen, with the balance of the argument seemingly in favor of the former; for, as stated by Washburn,

> "A by-product cannot be driven out of the market by competition, nor is the quantity in which it is produced determined by the demand for it. It must be produced without relation to the demand, and it must be sold without any relation to the cost."

SUMMARY.

The most salient aspects of our nitrogen problem are: a probably decreasing supply of organic nitrogen; a present greatly increased supply of by-product inorganic nitrogen with indefinite potentialities for enlargement; a maintenance for an uncertain but probably long period of years of the production of primary mineral nitrogen; and in the future, a possible greatly enlarged supply of primary manufactured nitrogen, produced by transforming power resources into fertilizer ammonia.

From the viewpoint of the economic aspects of the problem, there are three enormous wastes. The first is the waste of the resources of human life, brought about by the annual consumption of countless hours of human labor spent in the fruitless tilling of soils, the product of which is seriously curtailed through lack of nitrogenous plant food. The second is the waste of the kinetic energy of falling water. The third is the waste of the nitrogen resources of our enormous carboniferous deposits through destructive and wasteful utilization of bituminous coal. The resultant of these three negative forces is seen in increased hours of daily labor necessitated on the part of one or more components of our population — for the bread which the nitrogen could produce if applied to the soil must, in the failure of such application, be produced through the lengthening of the hours of daily toil. The basic difficulty in finding a remedy for these wastes is lack of co-ordination between industry, agriculture and commerce. As yet, however, the best intellects and the keenest minds in the country have failed to present a plan whereby this co-ordination may be secured. Meanwhile these wastes continue. Human life lived unproductively can never be relived; once the energy of falling water is dissipated in its tortuous route to the sea, it can never be regained; the loss brought about by the inefficient use of a single ton of bituminous coal can never be made good. The problem is much larger than merely that of securing a supply of fertilizer nitrogen.

NITROGEN IN RELATION TO CROP PRODUCTION IN THE MIDDLE WEST [1]

S. D. CONNER.[2]

Crops use nitrogen in greater quantities than they do any other plant food element. In cultivated soils large amounts of nitrogen are lost in the drainage waters, also considerable quantities escape into the air.

In an investigation at the Indiana Experiment Station (1)[3] in a study of virgin and cropped soils taken from 31 localities in the state, it was found that the cropped soils had one thousand pounds less nitrogen per acre than was contained in the virgin soils which had never been cropped. The sub-soils showed a loss of four hundred pounds of nitrogen per acre. The decrease from 0.18% nitrogen in the virgin to 0.13% in the cropped soil occurred on land which has had some clover and some manure to help maintain the nitrogen supply. The loss of phosphorus and potash was only ten percent.

With soils not originally so high in nitrogen the loss would be less, but with the system of farming followed throughout the Middle West, it is safe to say that the nitrogen supply of the soil is constantly diminishing. Stirring and aerating the soils, as in the cultivation of corn, causes a much more active nitrification and a much greater loss of nitrogen. In unpublished work at this Station by Coble and Chamberlain in 1920, nitrates were determined in the old rotation plots which have been under experimentation since 1889. Tests were made monthly from samples taken on plots in corn, oats and wheat.

TABLE 1.—*Nitrates in soil, corn, oats and wheat. Average from six rotations Purdue Station, 1920.*

(Parts NO_3 per million.)

	May	June	July	Aug.	Sept.	Average
Corn	9	26	56	64	16	34
Oats	5	3	10	8	10	7
Wheat	8	5	11	8	7	8

During August, when the nitrates were at the highest point, the soil in corn averaged sixty-four parts NO_3 per million, while the land in oats and wheat stubble averaged only eight parts per million.

[1] Paper read at the meeting of the Society held at New Orleans, La., November 8, 1921.

[2] Associate Chemist in Soils and Crops, Agricultural Experiment Station, Purdue University, La Fayette, Indiana.

[3] Reference by number is to "Literature Cited," p. 182.

At all times the land in corn contained more nitrate nitrogen than that in other crops. The active nitrification of cultivated soil when it is in corn no doubt explains why corn in the mid-west seldom responds to nitrogen fertilizer. It should be born in mind, however, that while corn does not seem to need nitrogen fertilization on these soils, it is the crop that is diminishing the supply of nitrogen the most rapidly.

Plot 4, Set III East, at the Indiana Station, has had wheat grown without fertilizer or manure continuously since 1889. Nitrogen was determined on the soil from this plot from samples taken at the start. Four determinations averaged .285% nitrogen. Samples taken in 1921, thirty-three years later, had only .215% nitrogen. This is a difference of 1,400 pounds nitrogen in the surface, a loss of over 42 pounds nitrogen per acre per year. As the yield has averaged less than 12 bushels per acre, the nitrogen loss has been about one-third more than that actually removed in the crop. This was on soil which always had a crop growing through the winter. Nitrogen losses would probably be much greater on soil in corn or on land which has laid bare in winter.

It has been pointed out by Bear (2) that the farther south a soil is situated, the more nitrogen is liable to be lost from it by leaching, particularly during the winter; and on the other hand, in the more northern climates the increase of soil nitrogen by bacterial processes, is slower.

While the soils of the mid-west may be ideally situated for greatest efficiency in regard to nitrogen supply, there is no question but that greater efforts must be put forth to replenish and conserve nitrogen. More legumes must be grown, more manure and crop residues must be conserved and returned to the land before maximum efficiency is obtained, even for an extensive system of agriculture. Still greater efforts are needed for intensive cropping.

Far too small a proportion of legumes to other crops is grown. In Indiana not more than one acre in ten of farm crops is in legumes. Ohio authorities have estimated about the same proportion. Clover constitutes over nine-tenths of the legumes in the middle west. In some counties along the Illinois line in northwestern Indiana, not one acre in one hundred is in clover or other legumes.

On four Indiana experiment fields, results have been obtained showing the value of a legume in increasing crops in a corn, wheat, clover or timothy rotation. When corn has followed the legume it has averaged 6.5 bushels per acre more than it has where following

the non-legume. The legume in the rotation caused an average increase in the wheat crop of 3.6 bushels per acre.

While phosphates and lime are usually the most profitable soil amendments that are used throughout the middle west, it should be remembered that much of the value of either phosphates or lime is obtained through the beneficial effect on clover. Without legumes and manure, liming and mineral fertilizers would lead to land ruin. For this reason, it may be said that nitrogen is the most important of all plant food elements.

It has been pointed out by many writers that for legumes to benefit the land most, they must be returned to the soil, either as a crop residue or in farm manures. A notable example of the mismanagement of a legume crop may be seen in northern Indiana, where cowpeas have been extensively grown on sandy soils. It has been found that cowpeas grew luxuriantly on these light soils. The cowpeas were cultivated in rows and harvested by pulling, the whole plant being removed from the field. Under such a system, the limited supply of organic matter and nitrogen was rapidly exhausted and the soil being left bare in the winter, many fields were ruined by the sand blowing away. It is necessary in growing cowpeas on such soils to return some organic matter and to seed to rye or similar crops to hold the soil and the nitrogen during the winter.

When a farmer has utilized legumes and farm manures to best advantage, available nitrogen may sometimes still be too low. In such cases, on some crops, it is profitable to use commercial nitrogen in the fertilizer. As a result of experiments on the North Vernon experiment field, 1913–1920, one dollar's worth of nitrogen in the wheat fertilizer on land receiving lime, manure, acid phosphate and potash, produced crop increases worth five dollars per acre per three year rotation of corn, wheat and clover. On the Worthington field, nitrogen produced only 71 cents profit under similar conditions, the manure and legumes evidently being sufficient to keep up the nitrogen supply.

SUMMARY.

Except on those soils which still have a large portion of unexhausted nitrogen left, the nitrogen problem is the most important soil fertility problem before the corn belt farmer.

Average Indiana soils have lost approximately twenty pounds of nitrogen per acre per year for the last half century and this loss is continuing. Some soils have lost over 40 pounds per acre per year and the time has arrived when the lack of nitrogen is seriously reducing yields.

Legumes and manure are needed in a much larger degree. Less than one acre in ten is in legumes in the Middle West. The proportion of legumes to other crops should be increased two or three times for best results.

On lands which have been exhaustively cropped some nitrogen in the fertilizer will be profitable, at least until more legumes are grown and crop residues and manure conserved and returned to the land.

Much of the profit in the use of lime, phosphate and potash is in the beneficial effect on legumes, thus indirectly these materials act as nitrogenous fertilizers.

LITERATURE CITED.

1. CONNER, S. D. The chemical composition of virgin and cropped Indiana soils. *In* Proc. Ind. Acad. Sci., 1914, 359–363.

2. BEAR, F. E. Adapting fertilizers to soils, farms, crops and climate. *In* Amer. Fertilizer, 52: 72h–72j. 1920.

THE POTASSIUM-NITROGEN RATIO OF RED CLOVER AS INFLUENCED BY POTASSIC FERTILIZERS.[1]

PAUL EMERSON AND JOHN BARTON.[2]

INTRODUCTION.

The most important question before soil investigators today is the development of a practical method whereby maximum crops may be produced without any overproduction in the soil of any element in an available form beyond the amount which the plant can utilize. Any procedure leading to such an overproduction would of course lead to losses. If too much attention is paid to solving the nitrogen problem, for instance, and in order to make the proper amount of nitrogen available to give the best growth, the forces that make potassium available are overstimulated (and results recently secured with red clover indicate this to be the case) then methods for the study of the fertility of soils which involve a consideration of the potassium problem and perhaps others, are certainly necessary. It appears that the question of raising maximum crops without any overproduction in an available form and consequent loss of the soil elements is of greater importance in the conservation of fertility than the question of the influence of any one element if all others concerned are disregarded.

[1] Paper read at the meeting of the Society held at New Orleans, La., November 8, 1921.

[2] Assistant Professor of Soils and Assistant in Soils, respectively, Iowa State College, Ames, Iowa.

Investigators have long recognized the fact that at least ten elements are essential for plant growth, four of these, namely nitrogen, phosphorus, potassium and sulfur may rightly be called "critical elements." Very little is known regarding the actual role played by phosphorus, potassium, sulfur and their compounds in plant nutrition and possibly less about potassium than any of the others. This may be due first, to the abundant distribution of potassium in nature and second, to the difficulties encountered in making accurate determinations. Practically nothing is known of the influence which this element may have on the assimilation of other elements by plants and *vice versa*. It is known that the nitrogen content, particularly of legumes, may vary widely. On the other hand, it is usually assumed that the phosphorus, sulfur and potassium content of plants are in more or less constant proportions. (In this paper the discussion will be confined strictly to potassium.) If an analysis shows that the plant contains a larger percentage of potassium than certain arbitrary standards, the fact is simply stated without further investigation. But even these standards may vary widely. The accompanying table shows the variability of nitrogen and potassium, as reported in three standard textbooks, and indicates that the potassium content of red clover may vary as widely as the nitrogen content.

TABLE I.—*Nitrogen and potassium content of red clover.*
(Recalculated in terms of percent.)

Reported by	Nitrogen	Potassium
Van Slyke	2.1	1.65
Henry	1.97	1.87
Hopkins	1.5	2.00
Hopkins (Agdel Field, Rothamsted)	2.65	.1.4
Hopkins (by Von Wolff)	3.05	1.13

It appears, therefore, that the potassium content of plants should receive the same consideration as that given to the nitrogen content. This is not because there is a crying need to conserve the former element, but because a proper regard for posterity demands that our crops be produced with the least possible waste. In other words there is a decided need for an accurate "Index of Productivity." Shall we determine it by measuring the effects of various soil manipulations or additions on plant growth; by determining the chemical composition of the plant; by lysimeter experiments; or shall we modify and develop our methods until they are capable of embracing the many and variable factors concerned with plant food production in the soil and use them as trial indices? Surely we cannot recommend any procedure that will supply, for instance, a stimulative

amount of nitrogen, if at the same time it causes overstimulation and probable losses of available potassium. The well known phenomena of the action of certain salts on plants may be used as an illustration of a possible overstimulation without injurious effects on the plant. It is known (16-page 14),[3]

"that single salts of potassium, magnesium, sodium or calcium in certain concentrations are toxic to plants, while mixtures of the same salts in the same concentrations are not. Thus, solutions of sodium chloride, magnesium sulfate, potassium chloride, and calcium chloride which, when used singly, killed plants whose roots were immersed in them for only a few minutes, formed, when mixed together, a nutrient solution in which the same plants grew normally."

An overstimulation, or an over-production of soluble potassium compounds in the soil, would not, therefore, in a normal soil, produce any injurious effect on plant growth but would, on the other hand make possible a loss of potassium by leaching.

THE ACTION OF POTASSIUM IN PLANT GROWTH.

According to Thatcher (16), the process of the photosynthesis of starch, or the changes necessary to its translocation, are so dependent upon the presence of potassium in the cell sap that the whole process stops at once if an insufficient supply is present. The presence of an ample potassium supply is necessary for vigorous growth of plants, while the absence prevents the possibility of the development of the carbohydrates necessary for vigorous growth. It has been demonstrated, however, (10) (12) that once in the cell the potassium is not immobile like iron, but is mobile like nitrogen and may translocate from old to new leaves or from old leaves and stems to the fruiting parts.

Hopkins and Aumer (7) removed all the soluble potassium from a soil and determined the power of decaying organic matter to liberate potassium from the "insoluble residue." They found that clover grown on this material contained about one-third as much potassium per gram as that produced on a normal soil, indicating that

"the actual requirement for potassium by clover may be much less than has been estimated from the composition of hay grown on ordinary soils."

They state that

"much of the potassium commonly found in crops may not be required but merely tolerated, being taken up by the growing plant because of the abundance in the soil."

Hall (6) likewise found an increase in the potassium content of clover; but takes a decidedly different viewpoint from Hopkins and Aumer as to the reason for such a condition. He says

"whatever may be the explanation, it is found in practice that the growth, etc., is very much promoted by a free supply of potash, and this is manifest upon sand and gravelly soils usually poor in potash."

[3] Reference by number is to "Literature Cited," p. 192.

POTASSIUM VARIABILITY IN PLANTS AS AFFECTED BY ADDITIONS.

While the literature regarding the potassium content of plants is somewhat limited, indications have been secured showing that most of the common crops are able to absorb larger quantities than are apparently necessary for normal growth. Fraps (5) found that corn, sorghum, kafir corn and mustard plants may take up an excess of potash according to the amount available in the soil, the percentage taken up decreasing as the amount of available potash decreases. Curry and Smith (3) found that clover from plots treated with potash contained an average of 0.25 percent more potash than clover from untreated plots. Frear and Erb (4) found a wide variation in the total potash content of corn, oats, wheat and hay crops. They found that on the average for a rotation, the crops harvested from the land that had been fertilized with potash carried off in a given weight of harvested material 40 percent more potash than a like weight harvested from unfertilized land.

It is a well-known fact that the addition of large amounts of soluble potassium salts are toxic to plant growth, but that amounts commonly added in agricultural practices are stimulative in most soils. Smith (15) found that additions of KCl, and K_2SO_4 in amounts up to 500 pounds per acre stimulated plant growth; but that larger amounts retarded growth. True and Geise (17), in growing red clover in quartz sand to which was added Shives' (13) R_5C_2 culture solution as a base modified by additions of KNO_3, KH_2PO_4, KCl and K_2SO_4, applied at the rates of 88.6 pounds and 433.2 pounds per acre, found that KNO_3 gave the greatest dry weight of tops. KH_2PO_4 was second in efficiency, while KCl and K_2SO_4 were less efficient than either of the other two, but produced approximately the same weights. Unfortunately, the plants were not analyzed in any of these experiments. Skinner and Reed (14) point out that clover is a heavy feeder of potash both in aqueous solution and in soil. They indicate that a higher proportion of potassium than of either nitrogen or phosphorus is used in the metabolic processes of the plant. Special attention is called to the fact "that the fertilizer requirement of any particular soil will upset this ratio."

No experimental data have been obtained on the feeding value of a high-potassium hay. Mr. J. M. Evvard, of the Iowa Agricultural Experiment Station informs us, however, that results recently secured with feeding pregnant ewes with potassium carbonate indicate very clearly the need of this element. If this can be supplied in the form of hay, many difficulties will be overcome. At the present time, a cooperative experiment is being planned whereby the feeding and

nutritional value of red clover hay containing varying amounts of protein and potassium will be compared.

It appears from the foregoing statements, that potassium must have an important function to perform in plant nutrition. As it is a mobile element, like nitrogen, capable of being translocated to different parts of the plant it seems that its presence must be necessary. Before studies can be made as to the proper amount to be supplied, it becomes essential to know the possible variations in percentage content of potassium in plants and the causes of these variations. In order to determine the effect of applications of common potassic fertilizers upon the potassium-nitrogen ratio of red clover the following series of studies have been completed.

PLAN AND METHODS OF EXPERIMENT.

In the following experiments, the plan was to compare the effects of potassium chloride, potassium sulfate and kainit (12 percent K_2O), added in practical amounts to a uniform soil type, upon the potassium and nitrogen content of red clover. The applications were supplemented by additions of manure, acid phosphate, and a combination of both. C. P. potassium chloride and potassium sulfate were added at the rate of 100 pounds per acre, while the kainit was added at the rate of 400 pounds per acre. Manure was applied at the rate of 10 tons and acid phosphate at the rate of 200 pounds per acre.

The soil used was a Miami silt loam taken from a field that had been previously cropped with potatoes. The length of time that this field has been under cultivation is not known; but is approximately sixty years. Accurate records of the cropping systems followed on this field could not be secured further back than 1917. No fertilizers had been applied between 1917 and the date of sampling and previous applications are extremely improbable. It is believed that an application of manure was made sometime previous to 1917. The cropping of the field for the past five years was as follows: 1916 (possibly) corn; 1917 oats and clover; 1918 clover; 1919 clover; 1920 potatoes. The soil was taken from the field in the late fall of 1920, partially dried, sieved and thoroughly mixed. An analysis of this soil showed that it contained an average of 16,600 pounds total potassium, and 23 pounds water-soluble potassium per acre.

This soil showed a lime requirement by the Truog method, of 2½ tons per acre. An application equivalent to two tons per acre in excess, or a total amount equivalent to 4½ tons calcium carbonate per acre, was made to the entire amount of soil used throughout the experiment. It may be noted here that it is generally stated in agri-

cultural treatises that the application of lime to a soil liberates potash from the soil minerals. That this supposition is erroneous is shown by the lysimeter experiments of Lyon and Bizzel (8) and MacIntire (9) and the extensive review of the subject by Plummer (11). In fact, lime applications may decrease the solubility of soil potassium, as indicated by Brown and MacIntire (2) and more recently by Briggs and Breazeale (1).

In this experiment thirty-two one gallon glazed earthenware pots were used, each being filled with the equivalent of 9 pounds of air dry soil, with the various fertilizers added on the dry weight basis. Moisture content was adjusted to the optimum 22 percent, additions, (by weight), being made three times each week in order to keep it constant. The arrangement of the pots and their duplicate treatments were as follows:

Pot	Treatment
1—2	Nothing — check.
	Series I.
3—4	Lime, 4½ tons calcium carbonate.
5—6	Lime, plus 100 pounds KCl.
7—8	Lime, plus 100 pounds K_2SO_4.
9—10	Lime, plus 400 pounds Kainit.
	Series II.
11—18	Same arrangement as Series I with the addition of 10 tons manure.
	Series III.
19—26	Same arrangement as Series I with the addition of 200 pounds acid phosphate.
	Series IV.
27—28	Lime, manure, acid phosphate, and KCl applied as above.
29—30	Lime, manure, acid phosphate, and K_2SO_4 applied as above.
31—32	Lime, manure, acid phosphate, and kainit applied as above.

The pots were seeded October 18, 1920, with red clover. When the seedlings were about two inches high they were thinned to seven plants per pot, spaced as nearly equally apart as possible. While the plants were growing, the position of the pots was shifted from time to time, to insure similar growing conditions.

While no attempt was made to inoculate the clover in these pots, an examination of the roots at the close of the experiment proved that all were well supplied with vigorous-appearing nodules.

The crop was harvested April 6, 1921 and dried for two days at 85° C. The dried plants were analyzed for total nitrogen and potassium by the regular official methods. The results of these analyses and the ratio existing between the potassium and nitrogen are shown in Table 2.

TABLE 2.— *Total nitrogen and potassium content of red clover from soils variously treated, their ratios. Results expressed as milligrams N. & K.*

Pot No.	Dry wt. of crop. mgm.	Total N in crop. mgm.	Average. mgm.	Total N in crop. percent.	Average. Percent.	Total K in crop. mgm.	Average. mgm.	Total K in crop. percent.	Average. percent.	Ratio K-N.
1	10.7	299.8	....	2.79	....	55.4	....	0.51	....	....
2	13.0	346.1	322.9	2.66	2.72	72.3	63.8	0.55	0.53	1-5.0
SERIES I.— *Potassium salts plus lime.*										
3	14.5	438.7	....	3.02	....	73.9	....	0.51	....	....
4	11.3	322.9	380.8	2.86	2.94	60.7	67.3	0.53	0.52	1-5.6
5	10.5	286.8	....	2.73	....	77.1	....	0.73	....	....
6	12.5	369.5	328.1	2.96	2.84	92.2	84.6	0.73	0.73	1-3.8
7	9.5	290.1	....	3.05	....	85.0	....	0.89	....	....
8	10.0	263.4	276.7	2.63	2.84	59.7	67.3	0.59	0.74	1-4.1
9	12.0	341.3	....	2.84	....	107.7	....	0.90	....	....
10	10.0	301.2	321.2	3.01	2.92	82.5	95.1	0.83	0.87	1-3.3
SERIES II.— *Manure plus potassium salts plus lime.*										
11	9.3	281.4	......	3.02	....	77.5	....	0.83	....	....
12	10.8	316.2	298.8	2.93	2.97	90.1	83.8	0.83	0.83	1-3.5
13	6.7	190.5	....	2.99	....	60.5	....	0.90	....	....
14	11.7	327.8	259.1	2.80	2.89	107.1	83.8	0.91	0.90	1-3.0
15	6.7	188.7	....	2.80	....	58.7	....	0.87	....	....
16	12.5	338.0	263.3	2.70	2.75	116.1	87.4	0.93	0.90	1-3.0
17	12.2	370.9	....	3.40	....	137.6	....	1.13	....	....
18	9.7	296.1	333.5	3.05	3.22	103.9	120.7	1.24	1.18	1-2.8

TABLE 2.—(*Continued*)

		SERIES III.—*Acid phosphate plus potassium salts plus lime.*								
19	8.2	227.4	....	2.77	....	54.6	....	0.66	....	....
20	10.5	279.5	253.4	2.66	2.71	69.6	62.1	0.66	0.66	1–4.0
21	9.7	272.3	....	2.80	....	80.8	....	0.83	....	....
22	13.2	379.1	325.7	2.87	2.83	112.9	96.8	0.85	0.84	1–3.4
23	16.5	492.3	....	2.97	....	109.4	....	0.66	....	....
24	15.2	391.8	442.1	2.57	2.77	109.6	109.5	0.72	0.69	1–4.3
25	15.2	425.2	....	2.80	....	169.5	....	1.11	....	....
26	15.5	423.4	424.3	2.73	2.77	146.8	158.1	0.95	1.03	1–2.6
		SERIES IV.—*Acid phosphate plus manure plus potassium salts plus lime.*								
27	8.2	246.9	....	3.01	....	98.4	....	1.20	....	....
28	9.5	284.5	265.7	2.99	3.00	101.7	100.1	1.07	1.13	1–2.6
29	9.5	303.4	....	3.19	....	111.7	....	1.17	....	....
30	15.2	449.3	376.3	2.95	3.07	133.5	122.6	0.88	1.02	1–3.0
31	13.0	360.6	....	2.77	....	128.4	....	0.99	....	....
32	8.2	228.9	294.7	2.79	2.78	69.6	99.0	0.85	0.92	1–2.9

DISCUSSION OF RESULTS.

From the results reported in Table 2, it appears that applications of lime produced very little if any, effect, upon potassium absorption by red clover. They had, however, a distinct effect upon the nitrogen content, caused greater growth, and consequently caused the plant to take more potassium from the soil; but the lime stimulated nitrogen assimilation so much in excess of potassium assimilation that it materially widened the K-N ratio. A further illustration of the lack of effect of lime on soil potassium was shown in Series I, in every case where potassium salts had been added. Wherever soluble salts were present the K-N ratio was narrowed in spite of the fact that the total dry weight of the crop from the potassium- and lime-treated pots was less than from those with lime alone.

The effect of manure, Series II, was to narrow the K-N ratio consistently. Manurial applications apparently depressed slightly the total dry weight of crop, as compared with the check, in Series I and Series III, but had a stimulating effect on the amount of potassium taken up. This stimulative effect is apparently not influenced by the addition of pure forms of potassium salts, as KCl, or K_2SO_4, but is markedly affected by the addition of the mixed salts in kainit. This absorptive effect is first apparent in the pots treated with manure and lime only. In this case, it narrowed the K-N ratio from 1–5.6 to 1–3.5. The ratio was still further narrowed by the addition of KCl and K_2SO_4. In both of these cases, based on the nitrogen and potassium content of one gram of dry material, there was apparently a slight depression of the nitrogen content and a marked stimulation of the potassium content. Kainit did not depress the nitrogen content, but increased the potassium content of the plants to a point where almost one-half the total potassium added was taken up by the plant.

The results in Series III were surprising in that the greatest dry weight of plants in the entire experiment was found here. The plants in the pots treated with acid phosphate and lime only did not show any increase in weight over the average of the entire series, but their K-N relationship shows that phosphorus has the ability to narrow the ratio and offset the widening effect of lime. Apparently potassium sulfate and acid phosphate applied at the rate of 100 and 200 pounds per acre respectively form the most ideal combination for plant growth in this particular type of soil, as evidenced by the crop produced. Potassium sulphate, however, did not narrow the ratio as much as acid phosphate alone possibly because of an increased stimulation of nitrogen absorption. The plants in the acid

phosphate- and kainit-treated pots took up more potassium than those which received any other treatments in this series. The clover in these pots not only took up an amount of potassium equivalent to the entire amount added but also a portion of the soils supply. The K-N ratio was significantly narrowed, without decreasing the rate of plant growth or producing any apparent injurious effect. This appears to be an excellent illustration of a possible effect of overstimulation. Had these soils been subject to leaching, as they would be under field conditions, the probability of loss is apparent. Many lysimeter experiments have shown that from five to two hundred and eighty pounds of potash may be lost per acre per year by this means. The amount so lost varies according to kind and type of soil and the treatment applied.

As no check pots were included in Series IV, no attempt will be made to explain the results obtained. Potassium chloride produced the narrowest K-N ratio of the series and the poorest growth. The action of K_2SO_4 and kainit was similar to that of the other series.

SUMMARY.

Pot-culture tests of the effects of applications of various forms of fertilizers to a Miami silt loam soil upon the amounts of potassium and nitrogen on red clover plants grown on it, lead to the following conclusions:

The amount of potassium taken up by red clover from a soil varies with the treatment applied to that soil.

The solubility of soil potassium, as indicated by the percent taken up by the plant, is increased by applications of manure, acid phosphate, or combinations of both.

The ability of red clover to take up potassium varies with the kind of compound supplied; from KCl, it is taken up in the smallest amounts; from K_2SO_4, in larger amounts; while the potassium in kainit, under some conditions, may be entirely taken up. As a rule, the effect of kainit on the amount taken up by the plant is more beneficial than either KCl or K_2SO_4.

Applications of lime in the form of calcium carbonate to an acid soil apparently has no effect on the solubility of native soil potassium, but may possibly overstimulate nitrate production.

The K-N ratio is widened slightly by applications of lime; but narrowed by applications of manure, or acid phosphate or both, in the presence of lime.

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LITERATURE CITED.

1. Briggs, L. J. and Breazeale, J. F. Availability of potash in certain orthoclase-bearing soils as affected by lime or gypsum. *In* Jour. Agr. Res., **8**: 21–28. 1917.
2. Brown, B. E. and MacIntire, W. H. The relation of certain water-soluble soil constituents in plats 16–24. Ann. Rept. Pa. State Col., 1910–1911. 105.
3. Curry, B. E. and Smith, T. O. Granitic soil potassium and its relation to the production of hay. N. H. Agr. Expt. Sta. Bul. 170. 1914.
4. Frear, Wm. and Erb, E. S. Condition of fertilizer potash residue in Hagerstown silty loam soil. *In* Jour. Agr. Res., **15**: 59–81. 1918.
5. Fraps, G. S. The active potash of the soil and its relation to pot experiments. Texas Agr. Expt. Sta. Bul. 145. 1912.
   ——— The effect of additions on the availability of soil potash and the preparation of sugar humis. Texas Agr. Expt. Sta. Bul. 190. 1916.
6. Hall, A. D. Fertilizers and manures. Dutton & Co., 1915. p. 171.
7. Hopkins, C. G. and Aumer, J. P. Potassium from the soil. Ill. Agr. Expt. Sta. Bul. 182. 1915.
8. Lyon, T. L. and Bizzle, J. A. Calcium, magnesium, potassium and sodium in the drainage water from limed and unlimed soil. *In* Jour. Amer. Soc. Agron., **8**: 81–87. 1916.
9. MacIntire, W. H. The liberation of native soil potassium induced by different calcic and magnesic materials, as measured by lysimeter leachings. Soil Sci., **8**: 337–394. 1919.
10. Pfeffer, W. F. P. The physiology of plants . . . Trans. by A. J. Ewart. Vol. 1, ed. 2, Oxford, 1900. p. 585–586.
11. Plummer, J. K. The effect of liming on the availability of soil potassium, phosphorus and sulfur. Jour. Amer. Soc. Agron., 13: 162–171. 1921.
12. Schimper, A. F. W. Zur Frage der assimilation der mineral-salze durch die Grüne Pflanze. *In* Flora Jahrg. 73 (n. R. Jahrg. 48). 207–261. 1890.
13. Shive, J. W. A three-salt nutrient solution for plants. Amer. Jour. Bot., **2**: 157–160. 1915.
14. Skinner, J. J. and Reid, F. R. Nutrient requirement of clover and wheat in solution cultures. Soil Sci., **12**: 287–300. 1921.
15. Smith, R. S. Some effects of potassium salts on soils. Cornell (N. Y.) Agr. Expt. Sta. Mem. 35. 1920.
16. Thatcher, R. W. The Chemistry of Plant Life. McGraw-Hill Book Co. 1921.
17. True, R. H. and Geise, F. W. Experiments on the value of green sand as a source of potassium for plant culture. *In* Jour. Agr. Res., **15**: 483–493. 1918.

INFLUENCE OF FERTILIZERS ON YIELD AND MATURITY OF SOY BEANS.[1]

By Geo. L. Schuster.[2]

INTRODUCTION.

Experimenters in soil fertility and crop response have observed that all crops do not respond alike to the same fertilizer and that a given fertilizer will not produce the same results on the various soil types with the same crop.

Scovell and Peter (11)[3] observed that for corn, potash is especially needed on the soils of their State and that wheat is greatly benefited by potash also. They also observed that the greatest profit in every instance was where potash was used.

Neale (9), at the Delaware Station observed that the greatest net profit in every instance resulted from the use of muriate of potash alone, the increased crop due to nitrate of soda being in no case sufficient to meet the increased cost of the fertilizer. He also observed that corn yielded most abundantly with nitrate of soda and muriate of potash, and that wheat gave the best return with nitrate of soda and acid phosphate.

Goessman (3), of Massachusetts Station, stated that sulphate of potash and magnesia on leguminous crops gave, in most instances, better results than muriate of potash. Tests with soy beans showed that potash had the greatest effect upon the increase and quality of the crop. In the soil tests with corn, potash was found to be the controlling factor.

Phelps (10), of Connecticut, reported that nitrogen had very little beneficial effect on either the total yield or the feeding value of cow peas or soy beans, but when supplied in the form of manure increased the yield nearly 9 bushels over that of mineral fertilizers.

Williams (12), of North Carolina Station, stated that ordinary applications of commercial fertilizers hastened the maturity of cotton. High nitrogen (N_3-P-K) applications on all types of soil studied generally produced larger percentages of total yield open at the first picking than high potash (N-P-K_3) applications.

Fellers (2), in his work with soy beans in New Jersey, found that applications of from 50 to 400 pounds of muriate of potash per

[1] Paper read at the meeting of the Society held at New Orleans, La., November 8, 1921.

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[3] Reference by number is to "Literature Cited," p. 197.

acre were followed by an average increase of about 10 percent in the yield of total dry matter and seed on both limed and unlimed plots; while nodule production was slightly stimulated on the limed plots but not on the unlimed. The fertilizer treatment which appeared to give the greatest return for the money invested on acid soils comprised from 200 to 300 pounds of acid phosphate together with a ton of lime.

Lipman and Blair (6), reported that soy beans inoculated and furnished with lime and soluble phosphate made a good growth and accumulated a high percentage of nitrogen up to the time the pods were half filled (hay stage) without the aid of readily soluble potash compounds.

Grantham (4 and 5) stated that for the State of Delaware, potash gives the best results of any single element on both corn and soy beans and recommended an application of 250 to 350 pounds per acre of a mixture of 400 pounds of acid phosphate and 100 pounds of muriate of potash on sandy soils for soy beans.

PLAN OF PRESENT INVESTIGATIONS.

The Wilson variety of soy beans was used in the investigations. They were seeded on tenth acre plots. Diagram 1 shows the arrangement of these plots and the treatment applied to each. The soil is that of the Sassafras series of the Piedmont Plateau province. The soy beans are seeded in a rotation with other crops as follows: (1) Corn (cover crop, rye and vetch), (2) soy beans, (3) wheat, (4) timothy and clover.

2. Sodium nitrate 10 lbs.	3. Acid phosphate 25 lbs.	4. Muriate of potash 7.5 lbs.	5. Sodium nitrate 10 lbs. Acid phosphate 25 lbs.	6. No treatment.	7. Acid phosphate 25 lbs. Muriate of potash 7.5 lbs.	8. Sodium nitrate 10 lbs. Muriate of potash 7.5 lbs.	9. Sodium nitrate 10 lbs. Acid phosphate 25 lbs. Muriate of potash 7.5 lbs.	10. Double quantity No. 9.	11. No treatment.	12. Basic slag 22.5 lbs. Muriate of potash 7.5 lbs.	13. Rock phos. 37.5 lbs. Muriate of potash 7.5 lbs.	14. Manure 0.25 ton.	15. Manure 0.5 ton.

DIAGRAM 1.—Showing arrangement of plots and treatments applied. Each plot is 2 rods wide and 8 rods long.

The average yields for the last six years are reported in Table 1, together with an analysis as to the maturity of the crop. The gram

weight of one pint was determined with a one pint grain tester. The data presented in the table show that the highest yield is closely correlated with the highest test weight and that the number of immature beans per 100 grams gradually increases as the yield decreases. The percentage of immaturity by weight is also recorded. This was determined by weighing the number of immature beans in 100 grams. It will be noted that there is a marked increase in the quantity of immature beans and a marked decrease in yield from the plots where muriate of potash has been omitted.

Muriate of potash in combination produces better results than where it is used alone. Heavy applications of manure (5 tons) produce the best results as to yield and maturity. Lyon (7) states that the analysis of average manure is approximately 10–2–12. It is evident that it must be either the nitrogen or potash that is producing the results from manure. Nitrogen on other plots is not giving high yields, so it must be fair to conclude that it is the potash of the manure that is producing the results here recorded.

TABLE 1.—*Showing correlation between immaturity and yield of soy beans.*

Plot.	Treatment per acre.	Gram wt. of 1 pint.	No. beans in 100 gr. mature	No. beans in 100 gr. immature.	Percent immature.	Average yield 6 yrs. bu. per acre.
15	Manure, 5 tons	400.0	680	0	0	31.6
10	Double quantity No. 9	392.5	645	3	0.2	26.6
9	Sodium nitrate, 100 lbs. Acid phosphate, 250 lbs. Muriate of potash, 75 lbs.	403.0	678	6	0.8	25.6
14	Manure, 2.5 tons	396.0	669	0	0	25.1
12	Basic slag, 225 lbs. Muriate of potash, 75 lbs.	388.5	602	43	4.4	23.3
7	Acid phosphate, 250 lbs. Muriate of potash, 75 lbs.	401.0	701	12	1.2	23.1
8	Sodium nitrate, 100 lbs. Muriate of potash, 75 lbs.	394.5	696	6	0.3	21.6
13	Rock phosphate, 375 lbs. Muriate of potash, 75 lbs.	388.5	733	39	4.2	21.5
4	Muriate of potash, 75 lbs.	394.5	730	4	.2	16.9
5	Sodium nitrate, 100 lbs. Acid phosphate, 250 lbs.	395.5	740	96	7.4	15.1
3	Acid phosphate, 250 lbs.	387.5	669	134	12.0	14.6
2	Sodium nitrate, 100 lbs.	389.5	667	103	9.3	14.2
6	No treatment	388.0	628	135	12.6	12.9
11	No treatment	375.0	621	221	19.6	12.2

FINANCIAL RETURNS.

The item that is always of practical interest is that of monetary returns. In computing the net returns, nitrate of soda was valued at $92.00 a ton; acid phosphate $18.00 a ton; rock phosphate $8.50

a ton; muriate of potash $384.50 a ton; basic slag $16.00 a ton; manure $3.836 a ton; and the soy beans at $2.85 per bushel.

The mineral fertilizer costs, with the exception of basic slag, were taken from wholesale quotations in the Market Report (8) of the Journal of Industrial and Engineering Chemistry, and 25 percent added for freight and commission to the retailer. The cost of basic slag was based on a quotation from the Tennessee Coal and Iron Company, and 25 percent added for the same reason. The manure was valued on the same basis as the mineral fertilizers according to the analysis given by Lyon (7). Thirty-five cents per acre was added for applying the fertilizers.

TABLE 2.—*Showing correlation between financial returns from fertilizers and immaturity of soy beans.*

Plot.	Treatment per acre.	Average yield for 6 yrs. bushel per acre.	Value of seed per acre.	Cost of fertilizers per acre.	Net returns per acre.	Percentage of immaturity.
15	Manure, 5 tons	31.6	$90.06	$19.53	$70.53	0
14	Manure, 2.5 tons	25.1	71.51	9.94	61.57	0
9	Sodium nitrate, 100 lbs. Acid phosphate, 250 lbs. Muriate of potash, 75 lbs.	25.6	72.96	21.62	51.34	.8
12	Basic slag, 225 lbs. Muriate of potash, 75 lbs.	23.3	66.40	16.57	49.83	4.4
7	Acid phosphate, 250 lbs. Muriate of potash, 75 lbs.	23.1	65.83	17.02	48.81	1.2
13	Rock phosphate, 375 lbs. Muriate of potash, 75 lbs.	21.5	61.28	16.36	44.92	4.2
8	Sodium nitrate, 100 lbs. Muriate of potash, 75 lbs.	21.6	61.56	19.37	42.19	0.3
3	Acid phosphate, 250 lbs.	14.6	41.61	2.60	39.01	12.0
6	No treatment	12.9	36.77	0.00	36.77	12.6
5	Sodium nitrate, 100 lbs. Acid phosphate, 250 lbs.	15.1	43.04	7.20	35.84	7.4
2	Sodium nitrate, 100 lbs.	14.2	40.47	4.95	35.52	9.3
11	No treatment	12.2	34.77	0.00	34.77	19.6
4	Muriate of potash, 75 lbs.	16.9	48.17	14.77	33.40	.2
10	Double quantity, No. 9	26.6	75.81	42.89	32.92	.2

The farm price of soy beans was taken from the Yearbook (13) for 1920.

Table 2 presents the net returns and the percentage of immaturity from the plots.

The plots are arranged in the order of the net returns, the greatest net returns coming first. A general statement may be made that all the potash carrying fertilizers yield greater net returns than those not carrying potash. Such a statement will not hold true, however, where potash alone was used. Potash has had greater increases in price in the last six years than any other fertilizer This will, in

part, explain why potash alone does not bring in any greater net returns. With the present lowering of the price of muriate of potash however it may be used more freely.

From these observations, manure produces the greatest net returns and produces no immaturity of beans on the Sassafras soil types. When manure is not available, an application of 250 pounds of acid phosphate and 75 pounds of muriate of potash per acre is recommended as being the most economical to apply. Sodium nitrate does not produce desirable results as to maturity or yield. Basic slag and rock phosphate are not so readily obtainable.

SUMMARY.

The presence of muriate of potash in fertilizers for soy beans brings the beans to maturity. This is in accord with the observations of Lipman & Blair (6).

Manure applications of 3 to 5 tons per acre give largest yields in which all the beans mature. It is believed the potash of the manure brings this about.

In the absence of manure, acid phosphate, 250 pounds, and muriate of potash, 75 pounds per acre, is recommended.

The above recommendations are based upon the experiments here reported and may be yield the largest net returns.

With lower-priced potash coming on the market, more potash should be used.

Nitrate of soda does not produce desirable results with soy beans, as to maturity, yield or financial returns.

LITERATURE CITED.

2. Fellers, C. R. The effect of inoculation, fertilizer treatment, and certain minerals on the yield, composition and nodule formation of soy beans. *In* Soil Sci. 4: ..., 1918.
3. Goessmann, C. A. Field experiments. Mass. Agr. Exp. Sta. Rept., 1893: 227–236.
4. Grantham, A. E. Soy beans. Del. Agr. Exp. Sta. Bul. 96, 1912.
5. Grantham, A. E. Annual report of director, Del. Agr. Exp. Sta. Bul. 119: 9, 10. 1918.
6. Lipman, J. G. and Blair, A. W. Vegetation experiments on the availability of phosporus and potassium compounds. N. J. Agr. Exp. Sta. Rept., 1917: 353–368.
7. Lyon, T. L., Fippin, E. O., and Buckman, N. O. Soils, their properties and management. MacMillan Co., 1916. 578–9.
8. Market reports. *In* Jour. Ind. and Eng. Chem., vols. 7–13: 1915–1921.
9. Neale, A. T. Del. Agr. Exp. Sta. Rept., 1892: 31–35.
10. Phelps, C. S. Field experiments with fertilizers. Storrs (Conn.) Agr. Exp. Sta. Rept., 1901: 122–147.
11. Scovell, M. A. and Peter, A. M. Corn experiments. Ky. Agr. Exp. Sta. Bul. 17. 1889.
12. Williams, C. B. Effects of different fertilizing materials upon the maturity of cotton. N. C. Agr. Exp. Sta., Cir. 12. 1914.
13. Yearbook, U. S. Dept. of Agr. 1920: 666.

SOIL TYPES AS A BASIS FOR SOIL INVESTIGATIONS.[1]

P. E. Brown.[2]

Until comparatively recently, practically all soil investigations have been planned and carried out with a magnificent disregard of the particular soil conditions; and the results of field experiments, greenhouse tests and laboratory investigations have been quite generally interpreted as applicable to all soils. Thus, while there seems to have been some appreciation of certain differences in soils, physical or chemical, if such difference were extreme, there has been in the past too much tendency to look upon " any soil as soil," using the term soil in a broad, unrestricted sense.

Our knowledge of soils has increased very rapidly during the past few years, however, by reason of many fundamental studies. It has become evident that soils may be classified into rather well defined series and types, being differentiated on certain definite characteristics. There has been, therefore, a growing tendency among soil investigators to consider seriously the significance of the soil type employed in their studies. There seems, indeed, to have developed some appreciation of the fact that the results of soil experiments are not necessarily applicable to any other soil conditions than those involved in the particular work and that all conclusions should be safeguarded from too broad an interpretation by the qualifying phrase " on this particular soil type."

Twelve years ago, in his presidential address before this Society, Dr. Geo. N. Coffey, then of the U. S. Bureau of Soils, called attention in a very clear and forcible way to the importance of the field study of soils, emphasizing the fact that soil differences may account for many of the " contradictory and seemingly inexplicable results obtained by different investigators or even by the same investigator." He asserted also that " the failure to recognize that the results secured upon one type do not necessarily hold true of another, is responsible in some measure for the distrust of farmers of the work of scientific investigators as well as of the unsettled and unsatisfactory condition of the field problem of soil fertility." How true this assertion is will be apparent when we consider how often the results of fertilizer tests from plots on an experiment station farm are used as a basis for general recommendations to farmers and how frequently the farmers

[1] Paper read at the meeting of the Society held at New Orleans, La., November 8, 1921.

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have failed to secure similar increases in crop yields. Is it any wonder if a farmer looks askance at station experiments after such an experience? Is it any wonder that investigators in the pure sciences have said that there is no soil science? Is it surprising that theories of permanent soil productivity have been varied, that controversies have raged and that the general public has failed to derive many of the benefits from soil investigations which the time and money expended on them should have insured?

However, a change of viewpoint in soil experiments is being gradually brought about, altho only very slowly and it is becoming a more generally accepted fact that the particular soil conditions are responsible in large part for the character of the results secured. Thus the weight of sentiment, the increasing knowledge of soil types which is being constantly secured, and perhaps I might add, also, the more accurate soil maps which are being produced, are accomplishing the desired result. Soil studies are now coming to be based more and more on the particular soil type and soil conditions and conclusions are being more carefully and conservatively drawn. But while the development of the soil survey work of the U. S. Bureau of Soils has been very extensive and while many more than the 800 soil types which Dr. Coffey mentioned in 1909 have been recognized and differentiated on the basis of fundamental differences, there are still some investigators who apparently fail to grasp fully the vital significance of basing their studies on the soil type; and many who perhaps thru oversight, to take a charitable view of the situation, draw broad general conclusions from narrow specific soil type experiments.

There are, of course, other factors than a lack of appreciation of soil differences which have brought about the publication in some cases of broadly conclusive, misleading statements and perhaps the making of unsatisfactory practical recommendations. The demands of the farmers themselves for definite advice, the attitude of administrative officers, urging the publication of practical results, the desire for publicity, the willingness to take a chance on how the recommendations work out, in order to gain public recognition, have all played a part in causing the "unsettled and unsatisfactory condition of the great problem of soil fertility" which Dr. Coffey referred to and which still exists, unfortunately, to some extent.

But I would not for one minute disparage the wonderful work which has been done in the past in soil experiments. I would not detract from the great practical good which farmers have derived from practising many of the methods of soil treatment which have been recommended. Many of the suggestions which have been made

have proved of inestimable economic significance. The improved methods of soil treatment and management which quite generally prevail are certainly sufficient evidence that soil investigations of the past have not been in vain and that the cost of such investigations has been well warranted. Furthermore, many of the fundamental studies along soil lines have brought out conclusions which are of general application. In other words, the results of many experiments are applicable to *all* soil types and there has really developed in the past decade a science of soils, for which no apology is needed.

There is no need to discredit all previous work, in order to call attention to ways in which future work may be improved. Such an extreme attitude not only casts discredit upon the profession as a whole in the eyes of the general agricultural public, but it is unfair to early investigators and it deliberately ignores the many investigations which lie at the very foundation of soil science.

In a recent publication,[8] a study by statistical methods of the results of the Ohio and Pennsylvania soil experiments is made and it is concluded that it is highly probable that "no fertilizer experiment as ordinarily conducted is possessed of sufficient practical value to justify the large expenditure of money, time and energy involved." The statement is made also that "our present knowledge of the enormous variability of all soils and plants renders the data from any given fertilizer plot of value only on that plot no matter how near the experimental one."

While it is true that many fertilizer experiments have been carried out on land which has not been surveyed and on which the soil types have not been determined, practical results of large value have often been secured. Even tho such experiments have been located conveniently and on college land which might be extremely variable and include more than one soil type, the conclusions drawn from them have led to recommendations which have proved of much use to farmers. It is undoubtedly true, of course, that the experiments would be of much greater value if the plots had been laid out on a definite soil type, of typical topography, without local soil variations of any kind and uninfluenced by previous variable methods of cropping and soil treatment. But to discard all fertilizer experiments, as the authors quoted would recommend, is not only unnecessary but would be deplorable. Fortunately, the radical suggestion is not likely to prevail and not even likely to be considered seriously. The unfortunate part about the publication of such statements is that they bring a certain amount of discredit upon all our soil experimental

[8] Lipman and Linhart, Proc. Nat. Acad. Sci., vol. 6, No. 11, p. 684.

work in the minds of other scientists and if disseminated extensively, would affect also the attitude of our constituents, the farmers, toward our recommendations.

But while it is not necessary to discard the results of all soil experiments carried out in the past, and they may serve to establish certain fundamental and practical principles governing soil management, the importance of determining the soil type is being recognized in the establishment of new experiment fields, with the idea of making the results of the greatest practical value as well as technically accurate. Hence, these new fields are very largely free from the objectionable features mentioned above and the results secured will certainly be applicable to the same soil type under the same climatic and seasonal conditions. When the soil type is determined and the plots are carefully laid out there is no question but that farmers operating on the same soil type will profit from the results secured, especially when the conclusions are safeguarded by being drawn only after results have been secured for several years. Furthermore, there is no question but that such results will yield fundamental and extremely valuable information regarding the particular soil type.

The significance of the soil type in field experiments must not be underestimated and the results obtained from any plot tests should be interpreted as applicable *only* to the particular soil type. No question of the value of the experiments can then arise.

The following table (Table 1) gives some results secured on various experimental fields in Iowa. It is evident from these that the soil type plays an important part in determining the results secured and that profitable treatments on one type may not be of value on any other type. Large increases in crop growth may occur on one soil and no increase at all on another. It can readily be seen also that certain treatments prove of value, altho indeed of variable value, on all the types, with the same crops. Thus, lime increases the clover yields and manure brings about larger growth of corn and oats. Other treatments, however, give different effects on the same crop on different soils.

In general this table illustrates the point that results obtained with fertilizers on one soil type will not necessarily be applicable to other types, but it shows also how certain treatments may be of value on practically all types. It gives evidence, therefore, that while the older soil experimental fields may yield results of general practical value, the newer fields, laid out on typical soil types, will prove of far greater usefulness in planning systems of permanent agriculture for soils in general, the particular system adapted to one type needing

TABLE 1.— *Yields of various crops under different treatment on soil types in Iowa*

Plot No.	Treatment	Marshall silt loam: Corn, bu. per acre	Marshall silt loam: Oats, bu. per acre	Marshall silt loam: Clover, tons per acre	Grundy silt loam: Corn, bu. per acre	Grundy silt loam: Oats, bu. per acre	Grundy silt loam: Clover, tons per acre	Marion silt loam: Corn, bu. per acre	Marion silt loam: Oats, bu. per acre	Marion silt loam: Clover, tons per acre	Carrington silt loam: Corn, bu. per acre	Carrington silt loam: Oats, bu. per acre	Carrington silt loam: Clover, tons per acre
1	Check	60.0	51.0	1.30	70.4	73.2	1.50	49.4	38.2	1.58	46.5	64.6	1.15
2	Manure	68.5	52.3	1.36	74.9	75.1	1.75	61.7	42.5	1.60	51.1	64.6	1.37
3	Manure+lime	68.5	61.8	1.56	82.2	74.8	2.10	65.8	48.8	1.87	63.3	61.9	1.42
4	Manure+lime+rock phosphate	69.3	63.6	2.89	88.6	76.5	2.30	63.7	65.8	1.91	66.1	76.8	1.67
5	Manure+lime+acid phosphate	73.7	60.4	3.40	101.4	85.1	2.75	68.6	73.3	2.60	60.8	74.8	2.00
6	Manure+lime+complete fertilizer	71.5	73.5	2.55	88.4	80.8	2.65	55.0	68.0	2.85	61.0	80.9	2.00

TABLE 1.—(*Continued*)

Plot No.	Treatment	Carrington loam: Corn, bu. per acre	Carrington loam: Oats, bu. per acre	Carrington loam: Clover, tons per acre	Muscatine silt loam: Corn, bu. per acre	Muscatine silt loam: Oats, bu. per acre	Muscatine silt loam: Clover, tons per acre	Grundy silty clay loam: Corn, bu. per acre	Grundy silty clay loam: Oats, bu. per acre	Webster silty clay loam: Corn, bu. per acre	Webster silty clay loam: Oats, bu. per acre	Clinton silt loam: Corn, bu. per acre	Clinton silt loam: Oats, bu. per acre	Clyde silt loam: Corn, bu. per acre	Clyde silt loam: Clover, tons per acre
1	Check	34.8	42.8	0.80	65.5	47.6	2.07	78.5	65.8	58.0	56.7	61.8	38.2	40.5	1.92
2	Manure	39.0	61.0	1.20	68.8	54.7	2.40	91.3	72.1	57.3	64.1	68.3	53.4	41.0	1.98
3	Manure+lime	40.0	64.9	2.10	75.5	59.2	2.65	92.0	74.2	58.1	63.5	70.6	55.2	51.8	2.24
4	Manure + lime + rock phosphate	52.7	65.5	2.05	77.2	64.9	2.69	95.3	74.2	64.2	69.7	73.5	63.7	61.5	2.28
5	Manure + lime + acid phosphate	50.3	72.1	2.50	81.1	62.2	2.75	99.0	72.1	76.5	76.3	70.8	63.7	63.0	2.54
6	Manure+lime+complete fertilizer	59.2	67.2	.....	78.2	57.5	2.91	98.5	78.5	80.0	68.9	73.0	65.8	83.3	2.34

much modification, perhaps, before being suitable for another very dissimilar type.

But it is not only in field experiments that the soil type is of importance. Greenhouse experiments, chemical studies and bacteriological results are quite as much affected by the soil type employed and too often such results are too broadly interpreted.

Table 2 shows some results from greenhouse tests on different soil types. Similar conclusions might be deduced from a study of this table as were reached from a consideration of the table of field experimental results. There can be no question but that all greenhouse tests should be planned on definite soil types if the results are to be of the greatest practical and scientific value.

Chemical studies on soils are also very largely influenced by the soil type. Careful studies are now under way in our laboratories to determine the relation, if any, which exists between the soil type and its chemical composition. It is realized, of course, that the differentiation in soil types cannot be made on the basis of chemical composition, but it seems quite reasonable to believe that the content of the different elements will vary between certain limits in any one type and that these limits will be different for other types. Particularly is this true when nitrogen and organic carbon are considered, two elements which are particularly significant in soil type separations.

The results of this study will be published later and no data will be given here. It is sufficient to say that the evidence so far secured points very definitely to the fact that the results of studies of the chemical composition of soils must be interpreted on the soil type basis to be of the greatest value.

Some results recently secured with legumes on two different soil types show that the nitrogen content of tops and roots may vary widely; how far the ratio may vary and how the effects on the soils from the growth of legumes will depend upon the soil type. These results serve to emphasize the fact that actual methods of soil management to maintain permanent fertility, at least from the nitrogen standpoint, may vary widely on different soil types.

Many other illustrations of the significance of the soil type in chemical studies of soils might be mentioned and reference given to published results, but it does not seem necessary to cite further work here. Several problems are now under way in our laboratories which involve a consideration of the relation of soil types to certain chemical soil conditions. Organic phosphorus in soils is being studied, hydrogen-ion concentration in relation to acidity and to other acidity tests, carbondioxide production in treated and in untreated soils,

TABLE 2.—*Greenhouse experiments with various fertilizer treatments on Iowa soil types.*

Pot No.	Treatment	Muscatine silt loam		Carrington loam		Clinton silt loam		Marion silt loam		Grundy clay loam		Carrington silt loam	
		Wheat grain in grams	Clover in grams	Wheat grain in grams	Clover in grams	Wheat grain in grams	Clover in grams	Wheat grain in grams	Clover in grams	Wheat grain in grams	Clover in grams	Wheat grain in grams	Clover in grams
1	Check	22.75	35.5	7.27	6.0	8.34	35.5	8.50	8.0	9.05	63.5	12.53	4.5
2	Manure	25.97	33.0	7.50	35.0	8.55	40.0	10.20	17.0	9.47	73.0	14.76	15.5
3	Manure+lime	30.42	45.0	8.75	57.0	9.30	56.0	11.85	12.0	9.48	75.0	14.67	22.5
4	Manure+lime+rock phosphate	28.55	57.5	9.17	58.0	8.49	49.0	11.45	25.0	11.18	76.0	13.93	21.0
5	Manure+lime+acid phosphate	31.42	63.0	7.77	63.5	9.97	63.0	11.10	39.0	10.35	78.5	15.22	28.5
6	Manure+lime+complete fertilizer	29.02	58.5	9.32	56.5	9.27	56.0	12.22	36.0	11.75	84.0	16.75	36.5

TABLE 2.—(*Continued*).

Pot No.	Treatment	Tama silt loam		Grundy silt loam		Webster silty clay loam	
		Wheat grain in grams	Clover in grams	Wheat grain in grams	Clover in grams	Wheat grain in grams	Clover in grams
1	Check	12.00	8.0	13.85	40.0	26.56	29.5
2	Manure	12.65	31.0	15.80	47.0	29.46	36.0
3	Manure+lime	12.86	51.5	16.61	54.0	31.71	44.0
4	Manure+lime+rock phosphate	14.03	57.0	17.70	62.5	28.95	46.0
5	Manure+lime+acid phosphate	12.72	64.5	15.25	62.0	35.80	45.0
6	Manure+lime+complete fertilizer	13.67	59.5	13.27	70.0	31.13	46.0

response to potassium fertilizers and the making of potassium available, the use of sulfur and changes which the element undergoes in the soil, the color of soils in relation to carbon and nitrogen, available phosphorus by various methods, the composition of humus, etc.

Many results of chemical soil studies which have been published have emphasized the applicability of the conclusions drawn to the particular soil type or the fact that the results varied on different soils. Surely in the light of results secured and from a consideration of the variations among soil types, it must be evident that no chemical studies on soils should be undertaken without a fundamental determination of the soil type.

From a bacteriological standpoint it seems almost unnecessary to call attention to the relation of the results secured in bacteriological studies to the soil type employed. Too much data has been published, however, which has been secured on one soil only and yet has been interpreted as broadly applicable to soils in general. When we consider the various factors which influence bacterial development in soils and then remember how these factors vary in different soils, it will be evident that bacteriological results will be influenced to a large extent by the soil type. Many experiments have shown this fact and while it is often difficult if not impossible, to distinguish and disentangle the various factors which are so closely allied, it is worthy of note that the variations in results may very generally be traced back to the soil type, other conditions being the same.

Our own studies of bacteria at different depths in soils, show how the soil type will govern the development of bacteria in the soil, affecting the numbers, the action and the distribution. Studies on bacteria in frozen soils, on occurrence and distribution of molds, on bacterial effects of lime, of manure, of rotations, of fertilizers, have shown how all bacterial and mold activities are influenced to a more or less extent by the soil type. Numerous experiments of others might also be cited which lead to the same conclusion. Other work now under way in our laboratories which involves the soil type, includes studies of bacteria in relation to crop production; the relation of bacteria to the nitrogen problem, to the phosphorus problem, to the potassium problem, to the sulfur problem and to the commercial fertilizer problem. The recognition of the fundamental importance of the soil type in bacteriological work will insure that our progress in knowledge along this line will be much more rapid and the value of the results secured will be much enhanced.

The question may arise in the minds of some as to how satisfactory the separation of individual soil types may be. One investigator,[4] in

[4] Pendleton, "A Study of Soil Types," U. of Cal. Pub., vol. 3, No. 12, p. 369

an introductory statement to a study of soil types by one of his students, says that he doubts the validity of the U. S. Bureau of Soils method of soil classification and mapping and he cannot see how such methods can serve us in scientific work. Incidentally it may be remarked that the conclusion drawn from the experiments is that the Bureau of Soils types show up differences when studied from various angles.

It is hardly necessary here to enter upon a consideration of the system of classification of soils which is being followed by the Bureau of Soils except to say that there is no question in our minds but that the method of differentiating soil types which the Bureau is following is fundamentally sound. Of course, there are cases where it is difficult to draw sharp distinctions; there are variations in types which sometimes seem too great to us; there are some separations which seem too fine, which involve too much of the personal equation; but as a whole we believe the principles on which the Bureau separates soil types are sound. This conclusion has been arrived at from a very careful study of all methods of soil mapping and classification and has not been reached without considerable thought. Certain other systems of classification were seriously and critically considered but they could not compare with the Bureau method. Hence, even tho the mapping of soil types is not an exact science, as the Bureau itself would admit, and tho there is room for improvement in certain methods of procedure followed in making soil maps, the soil type as established by the U. S. Bureau of Soils, we believe should be the basis for all soil investigations.

In conclusion I would emphasize the statement that I am convinced that we cannot do scientific work on soils without knowledge of the soil type and that if the conclusions are not based on the specific soil conditions they are absolutely worthless. If we are to have a real soil science, a science which will rank with other sciences, pure or applied, we must get on a scientific and sound basis and we can do this only by basing our experiments, field, greenhouse, chemical, and bacteriological, on a *soil* foundation, or in other words, on soil type separations. As our knowledge of soils increases and our soil types become more definitely and accurately defined, our results will, of course, become more valuable. But at the present time, sufficient progress has been made, in our soil survey work, so that we can base all our experiments on typical soils, with the assurance that we will secure results applicable to that same soil under the same climatic conditions, and that the conclusions drawn will be of the utmost accuracy scientifically.

THE INFLUENCE OF IRRIGATION WATER ON THE COMPOSITION OF THE SOIL.[1]

J. E. GREAVES.[2]

Water is applied to a soil primarily to meet the needs of the growing plant. Incidentally, it materially modifies the chemical, physical, and biological properties of the soil. (1) Water may increase or decrease the available plant-food of the soil without changing the total quantity; (2) water may carry from a soil plant-food, thus leaving it intrinsically less productive; (3) water may carry to a soil phosphorus, potassium, and nitrogen, therefore increasing its total plant-food; and (4) water may carry to and deposit in a soil "alkali" salts which in time will render it barren. The magnitude of these changes will be governed by the nature of the soil, the composition of the irrigation water, and the intelligence with which each is handled. It is, therefore, the purpose of this paper to summarize briefly some results which have been obtained at the Utah Experiment Station during the past ten years.

It is generally accepted today that many of the reactions which occur in the soil and tend to render soluble the various mineral constituents thereof are due to bacterial metabolism. It is also agreed that bacterial activity is a function of the water content of the soil. Our work has shown that the correlation between the water-holding capacity of the soil, as determined by the Briggs' (6)[3] modification of the Hilgard Method, and the ammonia produced in a soil is very pronounced. Twenty-two soils varying widely in physical composition all gave a maximum production of ammonia when the soil contained 60 percent of its water-holding capacity. Either above or below this concentration there was a decrease in the ammonia found, as may be seen from the following summarized results (1). The soil which received 60 percent of its water-holding capacity is taken as 100.

Water in soil, percent of water-holding capacity	Ammonia produced	Water in soil, percent of water-holding capacity	Ammonia produced
10	2	60	100
20	8	70	78
30	32	80	57
40	68	90	49
50	85	100	45

[1] Contribution from the Department of Chemistry and Bacteriology, Utah Agricultural Experiment Station, Logan, Utah. Received for publication November 28, 1921.

[2] Chemist and Bacteriologist.

[3] Reference by number is to "Literature Cited," p. 212.

An excessive quantity of water is more injurious than is an insufficient quantity. The results as obtained for this same soil for nitrification are given below:

Water in soil, percent of water-holding capacity	Nitrates found	Water in soil, percent of water-holding capacity	Nitrates found
10	11	60	100
20	17	70	40
30	31	80	9
40	62	90	0
50	85		

Small quantities of nitrates were being produced when the soil contained only 10 percent of its water-holding capacity of water; but when this is increased to 90 percent nitrification ceases. Therefore, an excessive quantity of water is more detrimental than is insufficient water. It is interesting to note that the optimum moisture content for soil for the production of many of our staple crops is nearly 60 percent of the water-holding capacity of the soil. (1, page 380.)

Under optimum conditions there may be produced from 50 to 100 pounds of nitric acid in an acre of soil during a season (5). This, when converted into a nitrate, becomes a valuable supply of food to the growing plant. This quantity of acid must of necessity liberate appreciable quantities of phosphorus and potassium in the soil which therefore becomes available to the growing plant. Therefore, keeping the soil supplied with 60 percent of its water-holding capacity of water is supplying the plant with both water and plant-food.

Moreover, the production of other acids by bacteria is dependent upon optimum moisture content. They obey the same laws. We find the quantity of carbonic acid produced in twenty-four hours in a good arable soil supplied with the optimum amount of moisture to be enormous. Some results indicate that this at times may be as much as 67 pounds per acre (7). The resulting carbonated waters would react on tricalcium phosphate of soil, forming more readily soluble acid phosphates, for tricalcium phosphate is four times as soluble in water charged with carbonic acid as it is in pure water:

$$Ca_3\,(PO_4)_2 + 2\,CO_2 + H_2O = Ca_2H_2\,(PO_4)_3 + Ca(HCO_3)_2$$

This would mean that sixty-seven pounds of carbon dioxid is capable of transforming 236 pounds of tricalcium phosphate into 280 pounds of the soluble diacid phosphate, provided all of the carbon dioxid is utilized for this purpose. This shows the tremendous potential solvent powers of bacteria.

Potassium occurs in soil mainly as silicates and is rendered soluble by the nitrous, nitric, sulfuric, acetic, lactic, butyric, and carbonic

acids generated by the bacteria. The last-named may react with inert potassium, producing available potassium according to the equation: $Al_2O_3K_2O.6SiO_2 + CO_2 + 2H_2O = Al_2O_3.2SiO_2 + 2H_2O + K_2CO_3$.

Where only sufficient water is added to a soil to moisten or even saturate it and none drains from the soil, plant-food remains in the soil to be utilized by the growing plant. But when more water is added than the soil can hold, it passes through the soil and carries with it the soluble minerals. The magnitude of this factor is exemplified by the enormous quantities of the various salts found in the waters of some lakes and oceans.

It is estimated that the rivers of North America carry to the ocean each year 474,000,000 tons of soluble constituents, a quantity sufficient to cover one hundred acres to a depth of nearly three thousand feet. Although the greater part of this is common salt and other non-valuable compounds, yet there are appreciable quantities of valuable salts, as is witnessed by the 33.4 pounds of potassium, the 22.8 pounds of nitrogen, and 3.5 pounds of phosphorus which we have found to be the average quantity contained in one acre-foot of the streams of the inter-mountain region. Even as much as 133.0 pounds of potassium have been found in some drain waters (4).

Carefully controlled experiments, extending over a period of nearly fifty years, have been conducted at the Rothamsted Experimental Station in England where the yearly rainfall is about 30 inches and the annual loss of nitrogen was found to be 35.5 pounds per acre. This is about the loss which experiments covering a period of ten years indicate occur at the Logan Greenville Experimental Farm where 25 inches and over of irrigation water is applied to a soil during a season.

The economic value of this is seen from the fact that this quantity of nitrogen in the form of a commercial fertilizer would cost $10.55. Moreover, grain grown on soil from which the available nitrogen is being continually washed is low in protein. Undoubtedly, the great merits of our dry-farm wheats as bread-makers is due in a large measure to the fact that the scanty rainfall is not sufficient to remove the soluble nitrogen from the roots of the growing plants. Yet certain farmers in irrigated districts leach out the plant-food with irrigation waters and then wonder why their soils are not productive.

The Valley of the Nile has become famous in irrigation history not because it was among the first irrigated districts of the world, but due to its extremely fertile fields, the fertility of which has been maintained throughout the ages. Other soils just as fertile have become barren. The Valley of the Nile owes its lasting fertility to the flood

waters which carry to it rich deposits of silt each year. Hence, we find that a soil's fertility may increase and not decrease through correct irrigation practices.

Where water is applied to a soil in moderation none leaches from it, and as the water evaporates it deposits within the soil its soluble and insoluble plant-food.

The following results have been obtained during the last few years at the Utah Experiment Station (4) in a study of the irrigation waters of the Intermountain region.

Hundreds of samples of water representing fifty-eight streams the majority of which are extensively used for irrigation purposes, have been analyzed. These waters vary in potassium content from 59 parts per million to only .79 part per million. Slightly over one-half of the waters contained 5 parts per million. The importance of these results becomes more obvious when we examine the pounds of potassium carried to an acre of soil by two acre-feet of water. This varies from 266.6 pounds in the case of the highest to 4.4 pounds in the case of the lowest, with an average potassium content of 33.4 pounds per acre.

These results are not without economic significance, for the highest amount of potassium found would be sufficient to produce 370 bushels of corn, 230 bushels of wheat or 34 tons of sugar-beets. The average for the stream is sufficient to produce 47 bushels of corn, 29 bushels of wheat, or 4 tons of sugar-beets.

Many of the soils of the intermountain region are rich in potassium; hence, this element is not as important as is phosphorus, which, although used by the crop in smaller quantities, is nevertheless at times the limiting factor in crop production.

The total phosphorus of the irrigation waters analyzed varied from traces to 5.47 parts per million. The great majority of them, however, contained less than one part per million. The average in 2 acre-feet of the water from these streams was 3.46 pounds, for that from the wells, 3.36 pounds; and for that from the drains, 1.82 pounds.

The phosphorus in two acre-feet of the water from the richest stream is sufficient for the production of 175 bushels of corn, 120 bushels of wheat, or 33 tons of sugar-beets. In the case of all the other streams, while not as high, it undoubtedly plays a part in maintaining the phosphorus content of the soil.

Even more important than the phosphorus is the nitrogen of the waters, for nitrogen is the limiting factor of crop production in most of the soils of the Intermountain region. This varies from traces up to 24.3 parts per million. The average quantity of nitrogen in two

acre-feet of the irrigation water is 22.8 pounds, while that in the highest is 132.2 pounds per acre. This would be sufficient to produce 186 bushels of corn, 114 bushels of wheat, or 17 tons of sugar-beets.

Moreover, there are in most of the soils of Utah numerous aërobic and anaërobic nitrogen-fixing bacteria. Our work indicates that these may increase the soil nitrogen twenty to thirty pounds per acre yearly. The quantity fixed, however, depends, among other things, upon the water in the soil (1).

Water stated as percent of water-holding capacity	Nitrogen gain	Water stated as percent of water-holding capacity	Nitrogen gain
10	30	60	75
20	25	70	100
30	25	80	90
40	38	90	45
50	45	100	25

It is at its maximum when the water contained in the soil is between 60 and 70 percent of the soil's water-holding capacity, and when the soil becomes filled with water the actual gain is only one-fourth what it is when the optimum moisture content is maintained.

These results probably help to explain the remarkable productivity of many of the irrigated soils of the arid regions. Some of them have been producing crops undiminished in quantity for upward of fifty years, and there is no reason why a limited few soils on which the richer irrigation waters are being used cannot continue for another fifty or one hundred years to produce maximum crops.

In addition to potassium, nitrogen, and phosphorus irrigation water carries varying quantities of soluble salts which may at times be concentrated enough to become a menace when the water is used for irrigation purposes. For instance, of the fifty-eight (2, 3) streams examined, the majority of which were extensively used for irrigation purposes, we find that thirteen of these carried soluble salt in dangerous amounts, if interpreted in the light of Hilgard's criterion that irrigation water should not contain over forty grains per gallon (571.2 parts per million).

The total soluble salt content of these fifty-eight streams varied from 60 parts per million to 1,312 parts per million. Moreover, it was found that a stream may be comparatively free from "alkali" during part of the year, but at other times it may be heavily charged with it. The melting of snow in the mountainous region usually has the effect of freshening the water, but local rains often have the opposite effect. In addition, drainage water, especially from "alkali" soils, greatly increases the soluble salt content of the stream.

The magnitude of the problem which confronts the users of these waters and the speed with which the soils may deteriorate is made clear by two examples. In one instance, a stream carried sufficient salts in it that one acre-foot would deposit on the soil 3,581 pounds of soluble salts, or twenty such irrigations would reach the enormous sum of 71,600 pounds — sufficient, if allowed to accumulate, to render the soil barren. Another stream would carry to the soil in the same time and under the same conditions over 15 tons of salt.

It is therefore evident that the intelligent use of irrigation water is a complex problem which requires a knowledge of the chemical, physical, and biological properties of the soil, together with a knowledge of the composition of the water and its influence upon the chemical, physical, and biological changes going on in the soil. One user of irrigation water may make of it a tool for making the desert bloom like the rose, whereas another user may through its use transform the most productive fields into a barren waste.

LITERATURE CITED.

(1) Greaves, J. E., and Carter, E. G. Influence of moisture on the bacterial activities of the soil. *In* Soil Science, v. 10:361-387. 1920.

(2) Greaves, J. E., and Hirst, C. T. Composition of the irrigation waters of Utah. Utah Exp. Sta. Bul. 163. 1918.

(3) Greaves, J. E., and Hirst, C. T. Composition of the waters of the Intermountain region. *In* Jour. Ind. & Eng. Chem., v. 10:1001. 1918.

(4) Greaves, J. E., and Hirst, C. T. The phosphorus, potassium, and nitrogen content of the waters of the Intermountain region. *In* Jour. Ind. & Eng. Chem., v. 11:451. 1918.

(5) Greaves, J. E., Stewart, Robt., and Hirst, C. T. Influence of crop, season and water on the bacterial activities of the soil. *In* Jour. Agr. Rsch., v. 9:293-341. 1917.

(6) Mosier, J. G., and Gustafson, A. F. Soil physics and management. J. B. Lippincott & Co., Philadelphia and London. 1918.

(7) Stocklassa, Julius. Biochemischer Krieslauf des Phosphat-Ions im Boden. *In* Centrbl. Bakt. (etc.), Abt. 2, Bd. 29:385-515. 1911.

A NEW MUCK SOIL PROBLEM AND ITS SOLUTION.[1]

M.E. Sherwin, R. B. Etheridge, and A. Dunham.[2]

The problem here set forth is presented because it is believed to be unique in the development of muck lands. A brief history of the land leading up to its present condition will, therefore, be given.

[1] Paper read at the meeting of the Society held at New Orleans, La., November 8, 1922.

[2] Professor of Soils, Instructor in Soils, and Fellow, respectively, North Carolina State College of Agriculture and Engineering, Raleigh, North Carolina.

LOCATION AND HISTORY

The area is situated in Beaufort and Washington Counties, North Carolina, and comprises a hundred square miles or less depending upon the particular character, or the intensity of that character, which might be considered as essential to the placing of the soil in the unique class herein noted. The several characteristics of the soil vary and do not appear in their greatest intensity coextensive with each other. Except when otherwise noted, the soil conditions mentioned in this paper are those of the muck soil on the Nissen Farms at Terra Ceia.

The agricultural development began with the dredging of canals, by private capital, prior to the first sale of these lands for agricultural purposes, about ten years ago. Considerable care was exercised by the development agent to sell the tracts only to buyers with sufficient capital to clear and complete the development.

To clear the land, the timber was cut and when dry, burned where it fell. "Stuck" corn was then grown and the land burned again the next spring. Two or three crops of corn were thus grown, after which the remaining stumps were pulled and together with remaining logs dragged into piles for a final burning.

At this time, the land was better drained by lateral ditches, usually ten to the mile, and cultivation with implements was begun. The yield of "stuck" corn probably averaged about fifty bushels per acre and this yield was maintained for a few years after cultivation began. The yields were then depressed and drainage became less effective. With the hope of remedying this condition, two lateral ditches were dug between each pair of original ditches making thirty ditches per mile. Notwithstanding these additional ditches, the land fails to drain properly.

FIELD OBSERVATIONS.

The muck layer originally averaged about four feet deep. Settling and decay have reduced this to about two and a half feet on the land which was first developed. The furrow slice drains well and is loose; but immediately below this, the soil remains extremely wet. Although no water will drain from it in a month's time, water can be squeezed out as from a sponge by pressing it in the hands, even after a long drought. It appears tight, close, and soggy. Corn roots will scarely penetrate below the furrow slice, with the result that corn fires badly. Soybean roots penetrate the subsoil and withstand the unfavorable conditions somewhat better.

In September, 1921, the unfavorable soil conditions were found not to be uniformly bad in any single field. The worst fields were

found to be speckled with good and poor spots. It was noted that the subsoil was wetter and more compact in the unproductive spots, tho a difference was not always evident in the surface soil.

Where much tramping by animals has been done the crops are uniformly poor. The running of a disc ten or twelve times across a field in the same track gives a strip of poor crop, due apparently to the increased packing of the subsoil. It seems that the less tillage the better, after a very moderate amount has been given. It seems also that tractors and heavy machinery which have given very favorable results on other muck lands will do this land considerable injury.

LABORATORY OBSERVATIONS.

In January, 1921, samples of soil were taken from one of these fields and sent to Washington, D. C. for a determination of its acidity. The lime requirement of these samples, as reported by the Bureau of Soils, is slightly in excess of one ton $CaCO_3$ per acre inch.

Another sample was sent to the Soils Laboratory of the North Caroline State College, where the following observation, were made: The colloidal matter of the soil was found to be negatively charged. It was also found to be precipitated by certain acids and acid salts. Thus, sulphuric acid, equivalent to 1 ton of sulphur per two million pounds of wet soil (the weight of about an acre 10 inches) causes perceptible clearing in twenty-four hours of a suspension which otherwise will not clear in several weeks. Larger applications of acid increase this rate of clearing. The breaking strength of puddled and dried briquettes made from this muck, to which sulphuric acid has been applied in puddling was diminished. Commercial acid phosphate used for fertilizer purposes when added at the rate of 50 tons per two million pounds of wet soil is about as effective as sulphuric acid equivalent to one ton of sulphur. Smaller applications than this did not show any effect on the rate of clearing. Lime and calcium carbonate caused the solutions in which these mucks were suspended to retain their full cloudy condition longer than the check solutions. These materials when used at the rate of one to five tons per acre increased the breaking strength of briquettes. Drying the soil at room temperature greatly reduces its power of absorption. The following tabulation shows the variation in the water-holding capacity of the soil before and after drying and when left in water at different temperatures:

Water-holding capacity as taken from the field........	264.93%
After being oven dried and then allowed to stand 4 days in water	18.30%

Same soil after standing 12 hours in water 80°C absorbed additionally 41.22%

Total absorbed 59.52%

This effect of drying on the water-holding capacity is easily noticed in the field.

COMPARISON OF SOIL FROM PRODUCTIVE AND UNPRODUCTIVE SPOTS.

Samples of soil were taken from the productive and unproductive spots noted above for comparison in the laboratory. The following is a tabulated statement of results obtained in the preliminary tests:

	Productive	Unproductive
Colloidal matter *	51.26%	48.87%
Loss on ignition of soil	85.68%	89.09%
Loss on ignition of colloid portion	93.66%	94.29%
Loss on ignition of non-colloid portion	77.28%	84.11%
Capillary water capacity	438.93	646.73
pH (determined colorimetrically)	4.5	4.5 to 5

* Material which remained in suspension after standing 3 days was blown off. The residue was again agitated; left to settle another 3 days; and again blown off. Material thus blown off is termed "colloidal."

It will be noticed that the colloidal matter is slightly higher in the productive spots than in the unproductive spots. This is contrary to what was expected from the appearance of the soils. The loss on ignition of the colloid portion is nearly the same regardless of productivity and the loss on ignition of the total soil not strikingly different. The loss on ignition of the colloid portion is five to eight percent greater than that of the total soil and ten to sixteen percent greater than that of the non-colloid portion.

The percentage of capillary water absorbed is very high for both soils; but is decidedly higher in unproductive soil. A comparison of the amount of water absorbed by these soils with that absorbed by the soil previously examined indicates a very wide variation in the water holding capacity depending upon the location from which the sample is taken. Much more work must be done before we can state positively which is most characteristic of the entire area or what the extreme limits are within the area.

Pending further investigation, the recommendation of ridged cultivation has been made to aid field practice; the object being to dry a maximum amount of the soil, thus limiting its colloidal matter and reducing its water holding capacity. There is field evidence on somewhat similar soil at Wenona that this treatment will give good results.

AGRONOMIC AFFAIRS.

PROGRAM FOR THE ANNUAL MEETING.

President Call has announced that the program of the annual meeting of the Society, to be held in Washington, D. C., in November, will consist chiefly of the following symposia:

"Phosphorus as Related to Crop Production," in charge of Dr. Firman E. Bear, Ohio State University;

"The Improvement of Agronomy Teaching," in charge of Dr. W. C. Etheridge, University of Missouri;

"Experimental Methods as Applied to Field Tests," in charge of Dr. H. H. Love, Cornell University.

It is planned that the first of these symposia shall occupy the program for the first day, and the other two for a half-day session each on the second day.

An important item of business at the annual meeting will be the decision on the question of whether the American Society of Agronomy will accept the invitation which has been extended to it to become one of the charter members of the proposed "Federation of the Biological Societies of America." President Call and the Editor attended the conference which was held in Washington, D. C., on April 23rd, under the auspices of the Division of Biology and Agriculture of the National Research Council, at which the proposal to form the new Federation was adopted.

WINTER MEETING OF THE SOCIETY.

A joint meeting of the Society with Section O of the American Association for the Advancement of Science will be held in Boston, next December. There will also be a separate session of the Society, at which there will be a symposium discussion of the topic "Soil Toxicity in its Relation to Economic Crop Production." The symposium is being arranged by Dr. B. L. Hartwell, of the Rhode Island Experiment Station.

NOTES AND NEWS.

On April 1st, C. B. Hutchison, formerly Professor of Plant Breeding at Cornell University, removed to Davis, California where he will be Director of the Davis Branch of the University of California College of Agriculture, and Professor of Plant Breeding.

C. L. Finch, of the Bureau of Markets and Crop Estimates of the United States Department of Agriculture, will be in charge of the enforcement work under the Grain Standards Act, with headquarters at Chicago, as successor to A. W. Herger, who died recently.

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PROGRESS IN STANDARDIZING THE INTRODUCTORY COURSES IN SOILS.[1]

M. F. MILLER.[2]

The standardization of courses in agricultural subjects has been practically impossible, thus far, because of the rapidly developing body of subject matter and because, as applied sciences, these courses have been greatly affected by local conditions. It would seem, however, that a condition has been reached in which the introductory courses in certain of the more fundamental subjects, such as soils, field crops, and animal husbandry, have come to embrace practically standard bodies of subject matter and that the time is ripe for efforts toward standardization. If approximate standardization can be brought about, it will make possible more rapid progress in the improvement of the courses, both in the selection of subject matter and in methods of teaching, while at the same time the transfer of credits between institutions will be facilitated.

There is little doubt that the subject matter of the introductory course in soils is more nearly uniform than that of other introductory agricultural subjects. This is because it is an outgrowth of the basic sciences of physics, chemistry, biology, and geology. Probably the subject has depended too largely on these sciences and has not developed a sufficiently distinctive type of subject matter; but when allowance is made for variations in local conditions, the material included in standard soils texts is essentially the same. The effect of local and climatic conditions on the character of the subject matter must always be recognized, but in most cases these variations offer no great obstacle to standardization. When, however, climatic conditions differ as radically as those of the group of states lying west

[1] Paper read at the meeting of the Society held at New Orleans, La., November 8, 1921.

[2] Professor of Soils, University of Missouri, Columbia, Mo.

of the hundredth meridian and those lying east of this line, a single course can scarcely be adapted to both sections. Doubtless the fundamental principles will be the same, but the problems of soil moisture storage, of irrigation, and of alkali control are of paramount importance in the West while the problems of fertilizer practice are of great significance in most of the eastern states. It seems probable, therefore, that the subject matter and practicums must be materially modified and rather distinct courses developed for the two regions.

The conference which was held at Lexington, Kentucky, in June 1920, was made up largely of representatives of the eastern group of states, and the course outlined there was intended primarily for use in that region. At about the same time a conference of men from the western states was held on the Pacific Coast, so that the prospects of developing distinct standardized courses for the two regions are very good. As three-fourths of the states are represented in the eastern group, I suppose the greatest interest centers upon the type of course best suited to this region.

The Lexington conference attempted to outline the essentials of a 5-semester-hour required sophomore course, or its equivalent, consisting of three class periods, one quiz or discussional period, and one laboratory or practicum period each week. Little attempt was made to outline the details of the subject matter of the course since it was taken for granted that this would embrace approximately what is included in standard texts written by men in the eastern region. The laboratory and practicum work was, however, rather definitely outlined. It included studies of minerals and rocks, some physical studies and some chemical studies, together with certain practical exercises and field trips. The fundamental idea in arranging the laboratory outline was to avoid lengthy laboratory exercises designed to teach laboratory technique and to substitute material which would give definite information about soils. The purpose of the entire course, as conceived by the conference, was to impart as much information to the student as possible and to avoid making it simply a preparatory course for further soils work. Since most of the students who take such a course will secure no further training in the subject, it is only fair to give a well-rounded course including a general survey of the field, one which is designed to meet the needs of the majority of the students.

It is, of course, too early to report any marked progress in the adoption of such a course in the various institutions, although a brief statement of the manner in which the soils instructors are

reacting to the plan, seems worth while. In answer to an inquiry, in the form of a brief questionnaire sent to the agricultural colleges throughout the country, 38 responded, 30 from the eastern states and 8 from the western states. The following is a brief summary of the most significant facts brought out by these replies.

	Eastern group.	Western group.
Approval or disapproval of course plan.		
Distinctly favorable	21	....
Favorable with modifications	6	7
Not distinctly favorable	3	1
Number using the course.		
Using course as outlined	5	....
Using course with slight modification	6	1
Giving a somewhat similar course but with material modifications	8	6
Giving a dissimilar course	11	1
Credit hours in course.		
Three credits or less	8	1
Three to five credits	18	5
Six credits or more	4	2
Year in which course is offered.		
Sophomore	19	6
Junior	8	2
Divided between two years	1	....
No information	2	....

It is surprising that so large a percent of the men reporting are in favor of the general plan. As only fifteen institutions were represented in the Lexington conference, all of the others were made familiar with the details of the plan through written and published statements. In spite of this fact, 70 percent of all the eastern institutions reporting, are favorable to the plan, while most of the remainder favor it with some modifications. Of the western institutions reporting, all except one are favorable to the plan, although as would be expected, most of them suggest that modifications are necessary in order to adjust it to western conditions. It is of interest to note that of the two men who dissented at the Lexington conference, one writes that he has practically concluded that the plan is a wise one, while the other offers no objections, except to insist that he still favors a larger amount of chemical and biological work than is provided in the laboratory outline. It may be of further interest to state that several of the institutions reporting were already giving practically the course as outlined or one very similar to it. Of eastern men who have been able to give the course a trial, either as outlined or with slight modifications, all favor it; although

most of them admit that the time has been too short to form a satisfactory opinion or to suggest definite changes. It should be said, too, that most of the men who are giving a course quite dissimilar to the one suggested are nevertheless in favor of the plan and express themselves as moving in that direction.

As might be expected, there is some difference of opinion with reference to the place which such a course should occupy in the curriculum. Slightly more than 60 per cent of the eastern men and 75 per cent of the western men favor the sophomore year, the remainder favoring either the junior year or a division of the course between the two years. Those who favor the junior year do so largely because of a desire to secure greater training in the basic sciences. It must be admitted that, so far as the efficiency of technical soils instruction is concerned, physics, geology and at least 10 hours of chemistry should be prerequisites; but for such a course as the one outlined, general inorganic chemistry and physics are the only courses absolutely essential. On the whole, the advantages of offering the course in the sophomore year seem to outweigh the advantages of more thorough training in the basic sciences. When thus offered, a better foundation is laid for advanced courses in field crops, and horticulture. It is also possible to reach a large number of students who return to the farm at the end of the sophomore year, and, a matter which is of special interest to soils instructors, it offers greater opportunity for students to take advanced soils courses.

The plan to make this introductory soils course one which meets the needs of the student who will take no further work in soils seems to have been well received. Several men comment on the wisdom of this plan and no objections are offered. There is little doubt that this matter is of fundamental importance and that it will utimately be favored in the majority of the institutions.

The greatest difference of opinion centers on the character of the laboratory work and practicums. Several men still contend for a considerable amount of detailed laboratory work, including much of a chemical nature. It must be admitted that such laboratory exercises have much to commend them, but it is practically impossible to arrange such a laboratory course which does not waste the average student's time in physical exercises of doubtful value, or consume much of his effort in learning the technique of chemical determinations.

Several men comment on the value of having the laboratory

work parallel that of the class room, which is made possible by this plan. Certainly this is good pedagogy. It is doubtless one of the strong features of the course. Others mention the importance and popularity of field trips and practical exercises which make it possible for the student to learn something of soils in the field. Such a form of instruction, properly organized, cannot but interest the student, and give him more valuable information than much of that which has heretofore been offered in the laboratory. It is a part of the attempt to give a well rounded course of particular value to the majority of the students.

The allotment of time between class, quiz and laboratory periods has not met with universal approval. This is because under some curricula it is impossible to arrange the suggested time allotment, because some men still insist on more laboratory work than the plan provides and because some object to devoting one whole period each week to a quiz. It is of course impossible to meet all of these objections and doubtless it is unnecessary. The utilization of the quiz period may well be left to the discretion of the individual instructor. The whole matter is one of pedagogy. If men prefer to use a part of each day as a discussional or quiz period there should be no objection. It is probably sufficient that the matter has been brought to the instructor's attention. It will serve to bring about better teaching and more attention to the pedagogy of the subject, which after all are among the greatest benefits to be derived from a standardized course. One instructor suggests that the success of the course as outlined depends largely upon the ability of the teacher to hold the interest of the students. There is little doubt that with only one laboratory period in a five hour course, much more depends upon the instructor than where more laboratory work is given. He must be alert. He must study methods of presenting subject matter. He can no longer depend upon a routine of laboratory work to consume the student's time.

The replies received from the various institutions, regarding the desirability of adopting such a course, show a remarkable unanimity of opinion. Of those who have given the plan a trial, all are in favor of its continuance. Just how generally such a course will be adopted in detail, only time will tell. Doubtless, many institutions will find it impossible to accept it exactly as outlined because of curriculum difficulties, since every curriculum is a compromise. Sometimes too there may be local difficulties which may prevent its adoption. On the whole, however, the indications are that con-

siderable progress is being made and the course as outlined seems to offer a good basis upon which to work toward ultimate standardization.

CONTROL OF COTTON WILT BY THE USE OF POTASH FERTILIZERS.[1]

LOY E. RAST.[2]

During the spring of 1920, nine five-acre fertilizer experiments with cotton were located on different plantations near Scott, Arkansas. The soil is alluvial river land known as "Lonoke very fine sandy loam." On each of these areas different fertilizers were used at each place; but all were applied at the rate of 500 pounds per acre.

FIG. 1. Healthy, vigorous plants on left were fertilized; on right, no fertilizer was used and all plants died.

One grower used 500 pounds per acre of a mixture containing 10 percent phosphoric acid, 3 percent nitrogen and no potash. The cotton plants in this field on both the fertilized and unfertilized areas in 1920 died so badly that no record was kept of the yield of cotton produced. The experiment was to continue on the same area for

[1] Paper read at the meeting of the Society held at New Orleans, La., November 8, 1921.

[2] Agronomist, Little Rock (Arkansas), office, Farm Service Bureau, Southern Fertilizer Association.

five years and something had to be done in order to get any results that would justify the expense for fertilizers. The writer suggested that 500 pounds of the same fertilizer as was used in 1920 (containing 10 percent available phosphoric acid, 3 percent nitrogen and no potash) be mixed with 500 pounds of kainit containing 12.5 percent potash. This mixture contained, as shown by analysis, 5 percent available phosphoric acid, 1.5 percent nitrogen and 6.25 percent potash, it was applied in the spring of 1921, at the rate of 1000 pounds per acre, before planting. The plants on the unfertilized area began to die long before they were mature and were evidently infected with the disease "cotton wilt." By harvest time, no less

FIG. 2. Part of the field to which potash fertilizer was applied, no wilted plants.

than 95 percent of the plants on the unfertilized area were dead and not a dead plant could be found in any part of the field where the fertilizer was used.

The fertilized area produced 1127 pounds of seed cotton per acre; whereas, the disease-infected part of the field to which no fertilizer was applied produced only 225 pounds of seed cotton per acre. Plants on an adjoining area to which 500 pounds per acre of fertilizer containing 10 percent available phosphoric acid, 3 percent nitrogen and no potash was applied before planting and to which 500 pounds per acre of kainit was used as an additional application after the plants

were up and growing, were equally resistant to the disease and just as prolific.

Certainly the control of cotton wilt by the use of commercial fertilizer was something new. It was evidently due to the potash in the fertilizer, but even the manufacturers and dealers of this material had never made such a claim for it. To preclude any chance of mistaken identity of the disease, Dr. John A. Elliott, Plant Pathologist

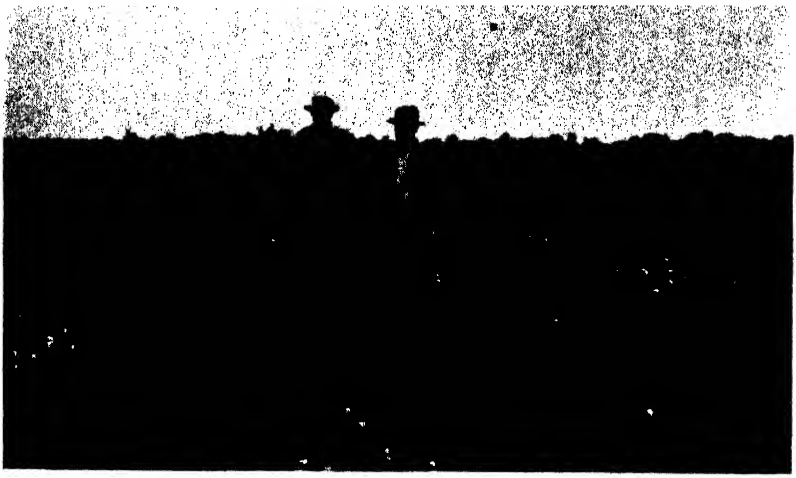

FIG. 3. Part of the field to which no fertilizer was applied. All of the plants died of wilt.

for the Arkansas State Experiment Station, was summoned and after a thorough inspection of the field, he wrote:

"Your experiment on Mr. ——————'s place was indeed striking. There is no doubt that the field is heavily infected with wilt, as practically every cotton plant on the check plot was dead or dying of the disease when I saw it. The plants on the adjacent kainit plot were remarkably free from wilt infection and I doubt if there was any material reduction in yield on this plot due to wilt. I do not attempt to make an explanation of the facts but to all appearances the treatment the kainit plot received enabled the plants this year to very largely escape wilt infection."

These experiments will be continued and various kinds and quantities of potash, both alone and in combination with other plant foods, will be used to determine their effectiveness in controlling this disease.

GRAINS GROWN IN COMBINATION FOR GRAIN PRODUCTION.[1]

C. A. Zavitz.[2]

For over a quarter of a century, various experiments in growing grains in mixtures for grain production have been conducted at the Ontario Agricultural College. It is interesting to observe in connection with the crop production of Ontario that the greatest areas in 1921 were used for the growing of oats, fall wheat, mixed grains, barley, husking corn, spring wheat, buckwheat, rye, peas, and beans, in the order here given. 618,289 acres were used for mixed grains in the past season, this acreage being almost equal to that used for the growing of winter wheat. It will be seen, therefore, that the growing of grains in definite combinations is occupying an important place in crop production in the Province of Ontario.

For six years in succession an experiment was conducted at the Ontario Agricultural College by growing oats, barley, spring wheat, and peas separately and in various combinations for the production of grain. Six mixtures having two classes of grain in each mixture, four having three classes of grain in each mixture, and one having all four classes of grain in combination were used each year. This made in all eleven mixtures, besides the four grains grown separately, requiring in all, fifteen plots. The experiment was conducted in duplicate, thus making thirty plots each year or one hundred and eighty plots in the six-year period. Varieties were selected which matured uniformly. The varieties were cut when they reached the proper stage of maturity and when dry were taken to the experimental barn and threshed. The grain was then cleaned and carefully tested, and the results recorded. The following table gives the average results in yield of straw and in yield of grain per acre of each of the eleven different mixtures as determined by twelve separate tests conducted in the six-year period. It also gives the comparative average results for the same grains when grown separately:

[1] Paper read at the meeting of the Society held at Toronto, Canada, December 28, 1921.

[2] Professor of Agronomy, Ontario Agricultural College, Guelph, Ontario, Canada.

TABLE 1.— *Yields of grains grown separately and in mixtures.*

Varieties of grain grown in mixtures.	Yield per acre. Straw. Grown separately (tons).	Straw. Grown in mixtures (tons).	Grain. Grown separately (lbs.).	Grain. Grown in mixtures (lbs.).
1. Barley and oats	1.56	1.74	1,935	2,261
2. Barley, peas and oats	1.47	1.67	1,489	2,101
3. Barley, wheat and oats	1.47	1.72	1,683	2,067
4. Peas and oats	1.52	1.77	1,873	1,988
5. Barley, peas, wheat and oats	1.43	1.71	1,682	1,955
6. Wheat and oats	1.52	1.68	1,624	1,921
7. Peas, wheat and oats	1.44	1.73	1,642	1,860
8. Barley and peas	1.33	1.56	1,740	1,760
9. Barley, peas and wheat	1.32	1.57	1,553	1,665
10. Wheat and barley	1.33	1.41	1,491	1,558
11. Peas and wheat	1.29	1.37	1,429	1,322

The foregoing results show that a mixture of barley and oats gave the highest production of grain, the average yield per acre being 2,261 pounds as compared with 1,322 pounds produced from a combination of peas and wheat under similar conditions. This makes a difference in yield per acre of 939 pounds of grain produced by the barley and oats in comparison with that obtained from the peas and wheat. It is interesting to note that, with only one exception, the grains grown in combination gave a greater yield per acre than the average production of the same grains when grown separately. As for instance, barley and oats when grown together gave 326 pounds of grain per acre more than the average of the two grains when grown separately. The only exception to the rule of the comparatively higher returns from the mixed grain is in the case of peas and wheat when the mixture gave an average of 107 pounds per acre less than the average of the two grains when grown by themselves. In the yield of straw, the mixed grains came the highest in every instance. The greatest yield per acre of straw was produced from the peas and oats grown in combination.

From the general results, it appears that the different classes of grains exerted an influence on the productiveness of the mixtures in the following order, namely:— oats, barley, peas and wheat, the oats having the greatest influence and the wheat the least. From a study of the detailed results of the experiment in growing the grains separately and in different combinations, it was found that in about 90 percent of the experiments the mixtures produced a greater yield per acre in comparison with the same grains when grown separately. Barley and oats, when grown in combination in the six-year experi-

ment, gave 193 pounds of threshed grain per acre more than the highest yielding grain when grown alone.

Having learned as the result of experimental work that a mixture of barley and oats was well adapted to a large production of grain, it became of importance to know the best proportions of these grains to use in combination to give the most satisfactory results. In the solution of this question alone, experiments have been conducted annually for fifteen years, there being three sets of experiments each running for five years. In all twenty-five different proportions of barley and oats have been carefully tested in each of five years. As the result of three separate tests, it was found that the greatest yield of grain per acre was produced by using a mixture of one bushel of barley (48 pounds) and of one bushel of oats (34 pounds) per acre, making a total of 82 pounds of seed per acre.

While there has been quite a decided advantage in growing different classes of grain in combination, there has been practically no advantage observed in numerous other experiments in growing in combination different varieties of the same class of grain. For instance, the results of experiments in growing different varieties of winter wheat in combination for five years in succession showed no advantage over growing the same varieties separately. This held true also in regard to the growing in combination different varieties of oats and again in growing together different varieties of barley, although in the case of barley, there was a very slight advantage from growing the varieties in combination.

Extensive experiments in the testing of different varieties of barley and of different varieties of oats were conducted over a series of years in order to ascertain the most suitable varieties for using in combination. In one test alone there were nineteen different combinations of varieties grown in duplicate tests in each of five years. An ordinary-ripening variety of barley and an ordinary-ripening variety of oats will not ripen at the same time. It is necessary to either use a six-rowed barley and an early variety of oats or a two-rowed barley with a late maturing oat according to the varieties which have been tested at the Ontario Agricultural College. The results of the experiments have shown that the highest yield and the best satisfaction throughout has been obtained from a high yielding six-rowed barley and a high yielding early oat. The O. A. C. No. 21 barley when grown in combination with the O. A. C. No. 3, the Alaska, or the Daubeney oats has given excellent returns.

Some farmers have been under the impression that, if a com-

paratively small quantity of rye, or wild goose spring wheat, or flax, was added to a mixture of oats and barley, they would receive in the resultant crop, not only as large a yield of oats and barley as if these two grains had been grown without any additional seed, but that they would obtain a fair yield of rye, or goose wheat, or flax, in addition. Results of numerous experiments have shown that this has not been the case and that so far no additional grain of any kind has been used with a standard mixture of barley and oats which has not caused an actual reduction in the total yield of grain per acre.

In experiments in which from eight to twelve different classes and varieties of grain have been grown in combination and in which the resultant crop has been separated into its different factors, it has been found that the greatest influence in high production has been exerted by barley and the second highest by oats.

From the various lines of experimental work which have been carried on, it will be seen that, if the right varieties and the right proportions of barley and oats are grown together under favourable circumstances, a comparatively high yield of the mixed grain may be expected.

EFFECT OF FERTILIZATION ON THE GROWTH OF SUGAR BEETS ON SOME MICHIGAN MUCK SOILS.[1]

M. M. McCool and Paul M. Harmer.[2]

There are several million acres of organic soils in Michigan. Usually these are spoken of as mucks; whereas in certain other states similar formations are termed peats. Only a relatively small percent of these lands is developed and inasmuch as many deposits are of high grade their development is only a question of time. Inadequate drainage, occurrence of frost, and lack of knowledge concerning their fertilization and crop adaptations, account for their undevelopment. Thus, it is desirable to know whether or not it is feasible to grow a relatively frost resistant and heavy cash crop such as the sugar beet on these lands.

The production of sugar beets in Michigan has been extensive for many years. In fact Michigan is one of three leading beet-sugar producing states, the average acreage of land devoted to this

[1] Paper read at the meeting of the Society held at Toronto, Canada, December 28, 1921.

[2] Professor of Soils and Assistant Professor of Soils, respectively, Michigan Agricultural College, East Lansing, Mich.

crop amounting to about 113,000. Sixteen factories, whose daily slicing capacity ranges from 500 to 1,500 tons each, refine the sugar from these beets.

The sugar beet producing areas are confined mainly to the Saginaw Bay and central Michigan sections of the State; although appreciable acreages are grown in eastern, southeastern and western Michigan. The acreage of land devoted to this crop and the tonnage obtained are given in Table 1, after V. M. Church.

TABLE 1.—*Sugar beets in Michigan — Total acreage, total yield, and average yield per acre — 1909 to 1920.*

Year.	Area harvested (acres).	Average yield per acre (tons).	Total production (tons).
1909	78,779	9.0	708,000
1910	117,500	10.3	1,208,000
1911	145,837	9.9	1,444,000
1912	124,241	6.8	839,000
1913	107,965	9.0	955,000
1914	101,263	8.5	857,000
1915	122,000	8.2	998,000
1916	99,619	5.5	544,000
1917	82,151	6.4	462,000
1918	114,975	7.9	890,000
1919	123,375	9.82	1,211,000
1920	129,400	8.6	1,106,000
Average	112,258	8.3	920,000

The majority of the beets are grown on the fine textured soils that have been weathered under rather poor drainage conditions, the topography being flat to gently undulating, this being especially true of the Saginaw Bay and eastern and southeastern Michigan areas. For several years this crop has been grown successfully on a small acreage of shallow muck or peat soils. It is generally considered that this can not be accomplished on the deeper mucks inasmuch as beets of inferior quality and low sugar content are produced.

Fertilizers have been used very sparingly for the production of sugar beets. The average rate of application is about 125 pounds per acre of low grade complete fertilizer. This is too parsimonious in case of many soils and it is probable that the rather low average yield obtained, as well as the increasing difficulty encountered in connection with diseases, can be ascribed to it.

OUTLINE OF PROJECT

In view of the general situation with respect to muck lands it was deemed advisable to inaugurate field experiments on the effect

of fertilizers on the tonnage, sugar content and percent of purity of beets grown on them. The fields upon which these investigations are being conducted are widely scattered and represent formations of different nature. All are located on extensive areas of muck and all are on deposits four or more feet in depth in the locality of the fertilizer plots.

The field at Buchanan is located on a well decomposed muck in the southwestern part of the State. It has an organic matter content of 74.85 percent and as ash content of 25.15 percent. The finely divided material is quite black in color, yet the soil is strongly acid. This muck is very impervious to water, crops grown on it in 1921 suffering for lack of drainage even to the edge of the drainage ditch, where the water level in the ditch was three or more feet below the surface. This lack of drainage is evident in the low crop yield reported below. The field had been cropped for several years and was in marked need of fertilization.

The Homer muck field is part of an extensive area in south central Michigan. This muck contains 83.24 percent of organic matter and 16.76 percent total ash. The material is quite woody and porous and is very slightly acid. This field is part of a tamarack swamp which burned over about 20 years ago and has been used to some extent for pasture since that time. It was broken for the first time in 1920, the sugar beets reported below being the first crop grown.

The field at Imlay City is on a rather woody, porous muck in the eastern part of the state. It has an organic matter content of 82.27 percent and a total ash content of 17.73 percent. The soil is not acid. It has been cropped for several years and shows considerable response to fertilization.

The field at Lum is only eight miles distant from that at Imlay City, yet the character of the deposit is markedly different. The muck is very well decomposed and quite firm under foot. It has an organic matter content of 68.13 percent and an ash content of 31.87 percent. The soil is not acid. The field has been cropped for a long period of years and is in marked need of fertilization.

Standard fertilizer treatments were given to the different portions of the fields. Nitrogen was added as nitrate of soda at the rate of 100 pounds per acre, phosphoric acid as 250 pounds of 16 percent acid phosphate and potash as 200 pounds of potassium chloride per acre respectively. Twelve tons of manure usually were applied per acre. The materials were distributed by means of fertilizer drills.

Experimental Results

Tonnage. The yields of roots in tons per acre from the variously treated plots of four deposits are given in Table 2. The Buchanan muck is markedly deficient in potash as shown by the remarkable response of several other crops, notably sunflowers, corn, mangels and stock carrots, to its application. The sugar beet yield was increased by the potash, yet the crop was practically a failure. Thus, fertilization may not overcome other deficiencies, such as drainage.

Table 2.— *Effect of different fertilizers on the yield of sugar beet roots.* (Expressed in tons per acre.)

Treatment.	Buchanan.	Lum.	Imlay City.	Homer.
None	0.7	3.5	5.9	11.7
Nitrogen	1.1	3.7	7.0	13.3
Phosphorus	0.4	3.2	7.7	13.4
Potassium	4.5	12.3	8.3	15.9
Nitrogen and phosphorus	0.9	4.5	7.3	11.0
Nitrogen and potassium	3.5	16.6	5.6	16.3
Potassium and phosphorus	2.8	14.1	7.5	17.4
Nitrogen, potassium and phosphorus	3.8	16.2	8.7	15.4
Manure	3.1	15.5	10.4	17.5

The Lum field responds amazingly well to applications of potash alone; but while applications of either nitrate of soda or acid phosphate alone do not result in increased yields, when either of these or both are applied along with potash they are quite effective.

The Imlay City muck was quite porous and too loose to yield best results with sugar beets; yet the mineral fertilizers increased the yields somewhat and the manure almost doubled the yield obtained from the check plots.

Lastly, the Homer muck appears to be an ideal one for the production of this crop. The unfertilized plots averaged eleven and nine-tenths tons per acre of roots. The fertilizer treatments, except where a mixture of nitrate of soda and acid phosphate was applied, increased the yields appreciably, as did stable manure. Potash was more effective than either nitrogen or phosphoric acid.

The yield of the tops was determined in the first three fields (Table 3).

Table 3.— *Effect of different fertilizers on yield of sugar beet tops.* (Expressed in tons per acre.)

Treatment.	Buchanan.	Lum.	Imlay City.
None	1.1	5.2	6.4
Nitrogen	1.9	4.1	6.5
Phosphorus	0.7	3.6	11.1
Potassium	3.5	6.1	7.4
Nitrogen and phosphorus	1.6	5.6	11.3
Nitrogen and potassium	4.7	5.5	6.5
Potassium and phosphorus	3.2	5.2	9.6
Nitrogen, potassium and phosphorus	2.9	5.1	10.7
Manure	2.1	4.7	8.6

Acid phosphate decreased the yield of tops produced on the Buchanan and Lum muck, whereas it increased it strikingly in case of the Imlay City deposit. When applied to the Buchanan soil, nitrate of soda stimulated leaf development somewhat in all cases except where acid phosphate was also used, whereas its effect was less consistent when applied to the Lum and Imlay City muck areas.

Sugar content. The above results show that satisfactory yields of sugar beets may be obtained on some muck soils especially when properly fertilized. It is equally important to know the sugar content of the beets grown under different conditions of soil and fertilization.

It has long been recognized that the element potassium is important in connection with the elaboration and transportation of carbohydrates in plants or that the presence of proper amounts of this element results in a more efficient leaf surface. A large leaf development of plants, such as the sugar beet and peppermint, for example, does not necessarily mean a high sugar or oil content. If the potassium is somewhat deficient the converse may result.

TABLE 4.— *Effect of different fertilizers on the sugar content.* (Expressed in percent sugar in the beet.)

Treatment.	Buchanan.	Lum.	Imlay City.	Homer.
None	13.8	10.8	14.4	13.8
Nitrogen	14.2	12.3	15.1	12.2
Phosphorus	10.0	12.9	14.2	12.4
Potassium	16.7	14.1	15.5	13.4
Nitrogen and phosphorus	11.8	11.2	14.4	12.8
Nitrogen and otassium	16.4	15.8	14.9	12.9
Potassium and phosphorus	14.2	15.9	14.2	14.4
Nitrogen, potassium and phosphorus	15.5	16.2	13.3	14.0
Manure	13.0	14.8	15.3	14.3

In the case of the Buchanan muck (Table 4) the addition of acid phosphate in a lowering of the sugar content of the beets, whereas nitrate of soda alone and also with acid phosphate increased it somewhat and when added along with the potash its effect was slightly depressing. The application of potash to this land proved to be the most effective in increasing the sugar content of the beets.

At Lum, the highest sugar content was attained in the beets grown on the land fertilized with a mixture of nitrate of soda, acid phosphate and potassium chloride. A mixture of nitrate of soda and acid phosphate did not appear to be as effective as did these fertilizers when used singly. The addition of the muriate of potash resulted favorably in all cases.

The differences in the sugar content of the beets grown on the various plots of muck near Imlay City were not great nor were the effects of the fertilizers consistent. At Homer, the nitrate of soda and acid phosphate when used singly or together without the potash appeared to have a depressing effect. The sugar content of the beets grown on the control plots and those produced on the plots receiving potash or manure varied but slightly.

Acre production of sugar. The amount of sugar produced per acre under the different conditions is interesting in that it shows the combined effect of fertilization on two variables, yield and sugar content. We have made such calculations and summarized them in Table 5.

TABLE 5.—*Effect of different fertilizers on the yield of sugar.*
(Expressed in pounds per acre.)

Treatment.	Buchanan.	Lum.	Imlay City.	Homer
None	129	504	1,133	2,153
Nitrogen	208	607	1,409	2,163
Phosphorus	53	550	1,458	2,215
Potassium	1,002	2,312	1,715	2,841
Nitrogen and phosphorus	142	672	1,402	1,877
Nitrogen and potassium	765	3,497	1,113	2,804
Potassium and phosphorus	530	2,989	1,420	3,341
Nitrogen, potassium and phosphorus	785	3,499	1,543	2,875
Manure	537	3,059	2,122	3,336

The most impressive points brought out with respect to the Buchanan muck are the effects of potash and the failure of this soil to produce satisfactory yields of sugar beets. At Lum, the action of potash is almost amazing, its presence changing this soil from a worthless condition to a satisfactory one so far as this crop is concerned. In case of the Imlay City muck, manure resulted in the largest sugar production on an acre, followed by potash alone and a mixture of the mineral substances carrying the three elements of plant food, nitrogen, phosphorus and potassium. The lowest amount of sugar produced was obtained from the plot that received nitrate of soda and muriate of potash. The salient features of the Homer project are the efficiency of stable manure, the favorable action of potash both alone and in conjunction with acid phosphate and the depressing effect of nitrate of soda when added together with either acid phosphate or the muriate of potash.

Purity. From the standpoint of the beet sugar manufacturer the sugar content and coefficient of purity are the factors which determine the value of beets for sugar-making purposes. A considerable per-

centage of the total weight of the beet consists of soluble solids, of which sugar forms the largest portion. Beets testing 12 percent sugar and 80 percent coefficient of purity, mean that 12 percent of the total weight of the beets is sugar and that 80 percent of the total soluble solids is sugar. The percentage of purity of the beets grown under various conditions is given Table 6.

TABLE 6.— *Effect of different fertilizers on the purity.*
(Expressed in percent.)

Treatment.	Buchanan.	Lum.	Imlay City.	Homer.
None	90.6	79.2	83.1	86.8
Nitrogen	89.1	80.6	83.9	84.0
Phosphorus	82.4	85.2	82.9	82.6
Potassium	94.6	83.8	88.1	85.2
Nitrogen and phosphorus	86.1	71.8	83.5	83.5
Nitrogen and potassium	91.5	87.8	81.0	82.9
Potassium and phosphorus	95.2	88.8	83.4	85.0
Nitrogen, potassium and phosphorus	93.5	85.8	79.6	86.2
Manure	87.3	87.9	85.8	86.0

The beets produced on the Buchanan muck were abnormal with respect to purity except in two instances. Both nitrate of soda and acid phosphate caused a depression in purity except where combined with potash. At Lum the lowest purity was recorded in the beets from the land treated with a mixture of nitrate of soda and acid phosphate, followed in turn by those from the unfertilized nitrate of soda and muriate of potash plots respectively, the differences in the purity of the others being small. The results are not consistent in case of the beets grown on the Imlay City muck. The highest purity was attained in the beets from the potash treated plot and those containing the most impurities were grown on the complete fertilizer land. The application of stable manure resulted favorably.

In all cases the beets from the unfertilized Homer muck contained less impurities than those grown on the treated land, although the differences were slight with the exceptions of those produced on the plots treated with acid phosphate alone, a mixture of nitrate of soda and acid phosphate and nitrate of soda and muriate of potash respectively.

THE EFFECT OF SUDAN GRASS ON THE BIOLOGICAL PROCESSES IN THE SOIL.[1]

PAUL EMERSON AND ROLAND D. FLETCHER.[2]

It is a well known fact that plant foods are constantly disappearing from soils regardless of the cropping methods which are followed. The greatest loss in a well regulated system of soil management is by assimilation by the plants and consequent removal from the soil. Some crops may remove more plant food than others and are spoken of as normal or heavy soil feeders according to the amount of soil-derived elements required for their growth. Sudan grass may be classed as a heavy soil feeder. It has an ash content of over 6 percent,[3] is very rank in growth and therefore may remove large amounts of soluble plant food from the soil.

Many workers have established the principle that there is a more or less direct relationship between the available plant food in the soil and its biological activities. It is usually assumed that in the competition for food between the soil organisms and the growing plant, the former may be limited in their activities by the needs of the latter. It becomes of interest therefore to determine what effect a heavy soil feeder like Sudan grass has upon the biological processes in the soil and, further, should the effect be detrimental, what methods of procedure will be necessary to correct the trouble.

The Department of Farm Crops of the Iowa Agricultural Experiment Station for a number of years has been studying methods and rates of seeding Sudan grass for hay and for seed, using a four year rotation of Sudan grass, soy beans, small grains and legumes. As these plots were of the same general soil type, and have each completed the rotation, they furnished an excellent basis for bacteriological determinations. Accordingly, a study was made of the biological activities of three plots, first a clover plot on which Sudan grass had been grown three years previously, second a Sudan grass plot and third, a virgin prairie soil. The study was extended to include the effect of additions of some common fertilizing materials both on the biological processes and on plant growth.

[1] Paper read at the meeting of the Society held at Toronto, Canada, December 28, 1921.

[2] Assistant Professor of Soils and Assistant in Soils, respectively, Iowa State College, Ames, Iowa.

[3] Farmers Bulletin 1126 of the U. S. Department of Agriculture shows an ash content of 7.94 percent and a yield of two to nine tons per acre.

Representative samples were secured in the fall from the Sudan grass plot, the clover plot and also from an area adjacent to these plots, which according to all available records was virgin prairie soil. These samples were taken shortly after the Sudan grass crop had been removed. This plot therefore was bare while the other two were supporting growing grasses. The samples were taken according to approved methods and thoroughly mixed before use for the bacteriological, chemical and greenhouse determinations.

LABORATORY STUDIES

The total nitrogen, phosphorus and carbon content of these soils together with the nitrate-nitrogen and lime requirement, determined by the usual methods, are shown in Table 1.

TABLE 1. — *Analyses of field soils.*

(Expressed in pounds per acre, based on 2,000,000 pounds per acre of soil.)

	Total nitrogen.	Total phosphorus.	Total carbon.	Nitrate nitrogen.	Lime requirement.
Clover soil	4,088	2,390	48,200	8.0	3,000
Sudan grass soil	3,586	2,228	47,400	10.8	4,000
Prairie soil	4,538	2,208	53,800	7.1	2,000

It is very evident that the heavy feeding habit of the Sudan grass has depleted the soil of nitrogen and phosphorus and indirectly of carbon, likewise has increased the acidity over that of the adjacent clover soil. As neither of these plots had received an application of manure for three years previous to the time of sampling and no other fertilizers have ever been applied, the results may be taken as fairly conclusive. It is surprising, however, that the nitrate-nitrogen is higher in the Sudan grass soil than in the others. This fact may be explained by the biological processes which are discussed below.

The bacterial and mold content of these three soils, (Table 2) based on the average counts of twelve plates, shows almost three times the number of bacteria in the clover soil as in the Sudan grass

TABLE 2.— *Average number of bacteria and molds in field soils.*

	Thousands of organisms per gram air dry soil.			
	Cook's No. 2 medium.		Lipman and Brown's modified synthetic agar.	
	Bacteria.	Molds.	Bacteria.	Molds.
Clover soil	3,607	406	4,822	127
Sudan grass soil	1,395	507	1,523	127
Prairie soil	25	240	747	120

soil. The mold content of the two cultivated soils are approximately equal. Both of the soils show a decidedly higher flora, from the standpoint of numbers, either bacteria or fungi, than the virgin prairie soil. However, it is extremely difficult, if not impossible, to interpret the crop producing power of a soil by numbers of microorganisms alone.

It has been demonstrated by many workers that the physiological efficiency of the biological processes in soils as measured by their ammonifying, nitrifying and azofying powers, bears no relationship to the total number of microorganisms contained in them. It was not expected that these soils would prove exceptional cases, but it was expected that the Sudan grass in particular would have an influence on those soil microorganisms concerned in the transformation of nitrogen. That such was not the case, however, was shown by an analytical study of the changes in the nitrogen compounds of both organic and inorganic nitrogen carriers added to the soils, the results of which are shown on Tables 3, 4, and 5. The production of ammonia, (Table 3); the formation of nitrates, (Table 4); and the utilization of atmospheric nitrogen, (Table 5), plainly show the ammonifying and the azofying powers in each of these three soils to be about equal; but the nitrifying powers of the Sudan grass soil is decidedly marked. The prairie soil did not possess the power to

TABLE. 3—*Ammonifying power of field soils.**

		Dried blood.		Cottonseed meal.	
Soils.	Ammonia in soil.	Ave. mg. nitrogen ammonified less check.	Percent nitrogen added ammonified.	Ave. mg. nitrogen ammonified less check.	Percent nitrogen added ammonified.
Clover	4.34	78.17	11.2	173.16	48.7
Sudan grass	1.68	93.98	13.5	132.60	35.8
Prairie	2.38	72.29	10.3	138.83	39.1

* Determinations made on 100 gm. soil plus 5 gms. organic nitrogen incubated seven days at room temperature and optimum moisture.

TABLE 4.—*Nitrifying power of field soils.**

		0.1 gm. ammonium sulfate.		0.1 gm. dried blood	
Soils.	Nitrates in soil.	Ave. mg. nitrogen nitrified less check.	Percent nitrogen added nitrified.	Ave. mg. nitrogen nitrified less check.	Percent nitrogen added nitrified.
Clover	1.6	trace	0.0	1.62	5.7
Sudan grass	4.5	1.62	7.6	5.10	18.2
Prairie	1.7	trace	0.0	0.0	0.0

* Determinations made on 100 gm. soil incubated with additions for four weeks at room temperature and optimum moisture.

TABLE 5.—*Azofying power of field soils.**

Soils.	Ave. mg. nitrogen found.	Ave. mg. nitrogen check.	Ave. mg. nitrogen fixed per gm. dextrose.
Clover	7.00	1.40	5.60
Sudan grass	7.21	1.40	5.81
Prairie	6.44	1.40	5.04

* 5 c. c. fresh soil infusion inoculated into 100 c. c. 1 percent Lipman and Brown dextrose solution, incubated 12 days at room temperature then kjeldahlized.

nitrify either ammonium sulfate or dried blood, and the clover soil showed little action on ammonium sulfate; but the nitrifying organisms in the Sudan grass soil had been stimulated evidently to such an extent that they were able to attack and nitrify both the organic and inorganic forms of nitrogen supplied. The latter action is possibly the explanation for the larger amounts of nitrates found in this soil in Table 1.

GREENHOUSE EXPERIMENTS.

The greenhouse tests were run to determine the effect of additions of various fertilizers on the ability of the soils from each of the three plots to produce crop growth, and also to determine the physiological efficiency of the microorganisms. The additions were made in amounts calculated on a two million pound acre basis to duplicate pots on each of the three soils, as follows:

Pots.	*Additions.*
1- 2	Nothing — check.
3- 4	Lime. Clover and Sudan grass soils 3 tons, prairie soil 1½ tons.
5- 6	Lime plus 8 tons manure.
7- 8	Lime plus manure plus 1,000 pounds raw rock phosphate.
9-10	Lime plus manure plus 200 pounds acid phosphate.
11-12	Lime plus manure plus 300 pounds 2-8-2 complete commercial fertilizer.

The pots were seeded to Marquis wheat on November 1, and, because of the necessity of finishing all determinations before a certain time, were harvested April 7, 1921, when the plants were at their maximum growth but before they had set seed.

Table 6 shows the green and dry weight of the wheat harvested from these plots. An examination of these data leaves no room to doubt the assertion that Sudan grass, in spite of its heavy feeding habits, does not materially injure the crop producing capacity of the soil, neither does it influence that soil in its favorable response to applications of materials commonly used as fertilizers. The check pots showed a better growth on the Sudan grass soils than on the clover soil but both slightly less than on the virgin soil. In the first

TABLE 6.— *Average weights and height of wheat harvested from potted soils.*

Pots.	Treatments.	Height, inches.	Green weight, grams.	Dry weight, grams.
	Clover Soil.			
1- 2	Check	20.5	22.4	6.7
3- 4	Lime	24.5	43.3	12.4
5- 6	Manure plus lime	23.0	42.1	12.0
7- 8	Raw rock phosphate plus manure plus lime	31.5	46.3	12.1
9-10	Acid phosphate plus manure plus lime	26.5	44.0	12.5
11-12	Complete fertilizer plus manure plus lime	30.0	48.3	12.9
	Sudan grass soil.			
13-14	Check	25.0	37.6	9.5
15-16	Lime	28.5	50.9	14.2
17-18	Manure plus lime	30.0	50.3	12.6
19-20	Raw rock phosphate plus manure plus lime	25.0	46.6	12.6
21-22	Acid phosphate plus manure plus lime	27.0	47.3	13.3
23-24	Complete fertilizer plus manure plus lime	31.0	51.7	14.2
	Prairie soil.			
25-26	Check	25.5	39.1	11.0
27-28	Lime	22.0	32.1	9.5
29-30	Manure plus lime	25.0	41.1	9.9
31-32	Raw rock phosphate plus manure plus lime	24.5	41.3	9.3
33-34	Acid phosphate plus manure plus lime	26.5	45.3	11.4
35-36	Complete fertilizer plus manure plus lime	23.5	36.4	9.1

two cases the response was equally marked to applications of lime, or lime and manure, with or without combinations of phosphorus or complete commercial fertilizer. The virgin prairie soil, however, was apparently depressed in its crop producing powers by nearly all of the treatments. This may be explained by an examination of that portion of Table 7 which shows the nitrate content and of Table 4 showing the nitrifying efficiency of the three soils. It is hardly conceivable that the nitrate-forming organisms were entirely lacking as indicated in Table 4; it seems more probable that their action was so slow that their products were utilized by other microorganisms as fast as formed. In the case of the potted soils, the growing plants were competitors with the soil organisms. In other words, the vitality of the nitrate-formers was so low that they were unable to oxidize the large amount of ammonia formed to nitrates in sufficient amounts to produce a rate of growth equivalent to the other two soils, and this in spite of the fact that the prairie soils contained a larger amount of total nitrogen than either of the other two. Table 7 also shows that the nitrifying efficiency of the flora of the Sudan grass

TABLE 7.—*Average nitrate-nitrogen and total nitrogen content of potted soils at end of growing period.*

(Expressed in pounds per acre.)

Pots.	Treatments.	Total nitrogen. Original soil.	Total nitrogen. Potted soil.	Nitrate-nitrogen. Original soil.	Nitrate-nitrogen. Potted soil.
	Clover soil.				
1- 2	Check	4,088	3,894	8.0	10.6
3- 4	Lime	....	3,948	....	9.2
5- 6	Manure plus lime	....	3,836	....	10.0
7- 8	Raw rock phosphate plus manure plus lime	....	3,780	....	13.6
9-10	Acid phosphate plus manure plus lime	....	3,808	....	12.2
11-12	Complete fertilizer plus manure plus lime	....	3,836	....	19.0
	Sudan grass soil.				
13-14	Check	3,586	3,416	10.8	15.0
15-16	Lime	....	3,528	....	12.2
17-18	Manure plus lime	....	3,584	....	12.0
19-20	Raw rock phosphate plus manure plus lime	....	3,612	....	10.2
21-22	Acid phosphate plus manure plus lime	....	3,684	....	12.2
23-24	Complete fertilizer plus manure plus lime	....	3,668	....	10.8
	Prairie soil.				
25-26	Check	4,538	4,088	7.1	9.0
27-28	Lime	....	4,172	....	13.0
29-30	Manure plus lime	....	4,228	....	9.6
31-32	Raw rock phosphate plus manure plus lime	....	4,228	....	9.8
33-34	Acid phosphate plus manure plus lime	....	4,284	....	9.0
35-36	Complete fertilizer plus manure plus lime	....	4,200	....	9.8

soil, as measured by the amount of nitrates produced, is greater than that of either the clover or prairie soils, thus indicating that this crop may stimulate nitrification under cropped conditions. This conclusion is also supported by the results showing the high nitrifying efficiency of Sudan grass soil recorded in Table 4, and is further emphasized by the results gained from the bacteriological tests of the potted soils after the crop was removed. The result of these tests, shown in Table 8, indicate the ammonifying, nitrifying and azofying powers of the three soils as affected by the different treatments. As there was only a slight variation between the checks and the different treatments, the various powers of each soil are condensed. Each result therefore represents the average of 24 determinations.

TABLE 8.— *Physiological efficiency of potted soils.*

	Ave. mg. nitrogen as dried blood ammonified.	Ave. mg. nitrogen as ammonium sulfate nitrified.	Ave. mg. nitrogen per gram dextrose azofied.
Clover soil	117.2	13.7	7.6
Sudan grass soil	158.8	11.3	8.5
Prairie soil	154.1	10.8	8.9

These results are comparable with those shown in Tables 3, 4 and 5. It was expected that the various biological powers would be increased by the favorable greenhouse conditions, but the facts stand out clearly that, that while the heavy soil feeding Sudan grass may reduce the total bacterial content of the soil, it does not influence those that are concerned in the transformation and rendering soluble of the plant food and, more important still, it may even stimulate those concerned in the transformation of nitrogen.

CONCLUSIONS.

Sudan grass, in spite of its heavy feeding habits, does not materially reduce the crop-producing power of this soil, neither does it influence the soil in responding favorably to the application of common fertilizers.

Sudan grass lowers the total bacterial content of the soil on which it grows, but apparently does not interfere with the physiological activities of the microorganisms which are concerned in the production of available plant food.

The organisms concerned in the transformations of nitrogen in the soil are favorably influenced by the growing of Sudan grass. This effect is particularly noticeable in its effect on the following crops.

THE PRODUCTIVENESS OF SINGLE AND DOUBLE FIRST GENERATION CORN HYBRIDS.[1]

D. F. JONES.[2]

Investigations dealing with the effects of inbreeding and crossing have resulted in a large amount of data showing the yielding capacity of hybrids from inbred strains of corn and it is here proposed to bring together these figures and to show what value they may have for the application of inbreeding and crossing to corn improvement.

[1] Contribution from the Connecticut Agricultural Experiment Station, New Haven, Conn. Received for publication, January 1, 1922.

[2] Plant Breeder.

As outlined previously (7),[3] the main value of inbreeding a naturally cross-fertilized plant comes in the opportunity it affords of controlling the heredity thru the pollen parent as well as the seed parent. Obviously, the results to be expected from the application of selection in self-fertilized lines depends largely upon the amount of material worked with and the ability to find potentially high-yielding inbred strains. Thruout the experiments on inbreeding begun by Dr. E. M. East in 1905 and carried on subsequently by Dr. H. K. Hayes and later by the writer, relatively few plants have been self-pollinated and there has not been any direct attempt to secure exceptionally vigorous inbred strains. The aim was to find out first as much as possible in regard to the principles underlying the inbreeding problem. The plants were self-fertilized at random. No discrimination among the seed ears planted was made except in the case of the strains selected on the basis of chemical composition of the seed. In most cases only one progeny was grown in each line and the number of plants raised seldom exceeded twenty-five or thirty in any one family.

Now that the importance of basing selection in self-fertilized lines on as large amount of material as possible is realized, a new series of inbred strains has been started from locally-adapted and proved varieties, with the object of obtaining a high-yielding type of corn well suited to southern New England conditions. These are now in the fourth generation. As yet no crosses have been made between these selections and the hybrids reported here are all from the original inbred strains, some of which are now in their sixteenth year of consecutive self-fertilization.

All of the strains used in producing the hybrids had been inbred for at least five years previous to crossing and were all characteristically uniform and much reduced in size, vigor and productiveness. Most of these inbred strains have been described previously. The ones chiefly used in making the crosses were four lines from Leaming corn obtained originally from central Illinois. (3, 6.) Three lines came from Burr's White, a dent variety selected for high- and low-protein by the Illinois Agricultural Experiment Station and were further selected in the same direction in successive self-fertilized generations. Four other high-protein strains were selected from a local strain of Leaming, and three from a variety of flint corn known locally as Burwell's Yellow. These selected strains have been described previously (4). In addition to these, two other strains of flint and two of floury corn have entered into the parentage of some

[3] Reference by number is to " Literature Cited, p. 252.

of the crosses. The larger part of the yields are from various combinations of the inbred strains from Illinois Leaming not selected for any particular character, together with the selected protein strains from Connecticut Leaming and Illinois High- and Low-Protein.

The hybrids resulting the first year after crossing two inbred strains are called single crosses, to distinguish them from the so-called double crosses which represent the combination of four inbred strains brought together by crossing again two first generation hybrids. Most of the combinations were grown to furnish the data on the effects of crossing on the development of different parts of the plant and upon variability which have been previously reported (6). Some of them yielded very poorly and would never have been grown for yield alone. All the results on yield, some of which have been published before, are here brought together and compared with the results from a variety test which has been carried on for a number of years in cooperation with the Storrs Agricultural Experiment Station. Over one hundred and fifty different varieties of dent and flint corn from different parts of the state and adjoining regions have been tested and these probably include most of the highest-yielding kinds of corn grown in this region.

The crosses and the varieties were grown under similar conditions. They were planted at the same time, harvested when ripe and a sample taken from each plot to determine the amount of actual dry matter produced. The plots consisted of single rows containing from twenty-five to fifty hills and the yields are calculated from the weight of the corn on the cob over to bushels of shelled grain with 12 percent moisture per acre. The plots were duplicated in different parts of the field and the higher yielding varieties and crosses were usually triplicated. Varieties and crosses of the same size of growth and time of ripening were grouped together, in order to obviate some of the effect of competition between adjoining rows, altho in some cases the yields are probably somewhat distorted by the unequal growth of adjoining rows.

So many different hybrid combinations have been grown that it does not seem to be worth while to report all the yields individually. All that is attempted here is to compare the yielding power of the parental inbred strains and the two classes of hybrids with that of the best varieties grown in the state. For several reasons, it is difficult to make a fair comparison. Much of the inbred material used in making the crosses is out of varieties which came originally from Illinois. It has been grown and naturally selected for our conditions here for so many years that it is obviously impossible

to compare the crosses with their original parental varieties either in Connecticut or in Illinois. On the other hand to compare them with local varieties brings in many unknown factors. As a general rule, the highest yielding local varieties are more productive here than any varieties recently introduced from the western and southern corn growing districts, altho such corn will usually grow satisfactorily and in most seasons will mature fairly well.

All of the corn has been grown at Mt. Carmel which is about ten miles from Long Island Sound and is in the same biological zone as the central corn growing area. The Upper Austral zone (8) lies mainly in the states of Ohio, Indiana, Kentucky, Illinois, Missouri, Iowa, Kansas and Nebraska but it extends eastward at the low altitudes and includes Long Island and skirts the northern shore of Long Island Sound.

Seed of the Leaming corn, from which the inbred strains from Illinois were derived, was obtained from the original source and yielded at the rate of 75 bushels per acre in 1916 and 90 bushels per acre in 1918. In 1916, it was surpassed in productiveness by 20 local varieties, the highest yield of the latter being 95 bushels per acre and four local varieties outyielded it in 1918, the highest yield being 96 bushels. Other varieties from Illinois which have been tested are Funk's 90-Day and Sutton's Yellow Dent. In production of grain these varieties have not yielded as well here as the best local varieties.

The single and double crosses derived from the Leaming and Burr's White stock have matured in from 120 to 140 days from planting. Most of the highest yielding local varieties require the same amount of time to ripen properly. However, many of the varieties included in the variety test matured from 10 to 20 days earlier. The crosses between the Connecticut Leaming strains and between the flint strains required about the same length of time. On the whole, many of the varieties matured earlier than the crosses and hence are somewhat handicapped in a comparison on the basis of yield, as it is a general rule that the longer a corn plant grows the more it yields provided it matures properly. For this reason, and because different numbers of crosses and varieties were grown, the figures for yield given in Table 1 must be studied with considerable caution.

The results are given in the form of frequency distributions, divided into classes of ten bushels difference in yield. For the reasons given above, the averages for each group mean very little. Attention is called particularly to the distribution of the yields.

From this it is believed possible to derive fairly reliable conclusions. Each entry in Table 1 is the actual yield of a single plot calculated to bushels per acre. Each replicated plot appears separately as the yields of different rows of the same variety or cross are not averaged. Check plots were grown in every fifth row, but the yields given in Table 1 are not corrected to the check rows as they are in Tables 2 and 3. The reason for this is that, in all the years of the test except the first, one single or one double cross was used to plant the control plots. The comparison of the yields of these check rows with the varieties growing in adjoining rows which is made in the frequency distributions shown in Table 1 gives the most convincing evidence of the value of corn hybrids.

The inbred strains after being reduced to uniformity and constancy have yielded, in the four years, from 5 to 65 bushels per acre and have averaged altogether from 20 to 35 bushels. This is from one-half to one-third of the yield of normal plants under the same conditions. Of the eighteen different inbred strains grown. nine have been selected for high protein and for this reason are expected to be somewhat lower in yield than strains not so selected. The one inbred strain selected for low protein has been a consistently good yielder. One of the Illinois Leaming strains has given the best results on the whole, of any of the inbred strains. The plants are sturdy growers, stand up well in the field when others are blown down, and their foliage is dark green in color and free from the mottling and flecking during the later part of the season which is a conspicuous weakness of many inbred strains. The plants are appreciably less subject to smut parasitism in Connecticut (5) and the ears are seldom moldy.

But, even at its best, this strain does not compare with the original variety in productiveness. Many of the inbred strains, particularly the high-yielding ones, are notably deficient in pollen production. Some are very nearly sterile, particularly during exceptionally dry or extremely hot weather. The yields reported here were made possible by pollen from other plants in the same field. When these plants are grown in isolated fields and are dependent upon their own pollen or that from other inbred strains their production of grain is usually considerably reduced.

The poor production of inbred plants is one of the chief handicaps in utilizing crosses of inbred strains. There is a good reason to expect that when corn is extensively selected in self-fertilized lines that much better inbred plants can be secured. It is important to keep the pollen production sufficiently high to insure a full setting

of seed in open pollination. Our experience shows that the results obtained with hand pollination are not always a reliable guide as to what the plants will do in the open field.

The next point to be considered is the yielding ability of first generation crosses between these inbred strains. Such crosses were first grown in 1908 and reported by East (1). More extensive data from some of the same strains further inbred and the crosses grown in 1909 and 1911 were given by East and Hayes (2). A few crosses were also grown in 1913 but not reported. In 1916 and 1917 an extensive series of crosses between many of these same strains still further inbred were grown by the writer (6). The yields from these are included in the data given here. While there is no exact way of comparing the results of one season with another there is no indication that crosses between strains inbred for 10 generations or more are more or less productive than the same crosses made earlier.

Noll (9) reports a series of first generation crosses between strains inbred from two to four years. The yields of the hybrids are compared with those obtained from the original variety. While some of the crosses exceeded the variety in yield, no marked superiority was obtained. These results agree in general with the data given here. During the four years tested, in only one year, 1919, did the combinations of two inbred strains, or single crosses as they are called, clearly outyield the varieties grown under the same conditions. In 1918, only four single crosses were grown and these can be left out of consideration. In 1919 however, many single crosses surpassed the highest yielding varieties with a wide margin and the distribution of the yields shows the superiority of the crosses. In the other three years, no advantage was derived from the single crosses as compared to the varieties.

In 1917, crosses of several varieties with one inbred strain (the best one so far found) as the pollen parent were grown and their yields are included in Table 1. These are of some interest as they compare with the grading-up practice in animal breeding where a pure bred sire is used with grade stock. The yields averaged about 10 per cent better than the varieties taken all together.

When the inbred strains were reduced to their low level of vigor after five or more generations of self-fertilization it was noticed that the first generation hybrids produced from such strains were handicapped at the beginning of the season. The seedlings were smaller in size and slower in growth at the start. Growth curves (6) show that such plants do not attain their maximum rate of development

until about the middle of the season. The hybrid seeds are borne upon weak inbred plants and for that reason are much smaller in size and have less stored food for the young plants to start on than the large variety seeds grown on vigorous plants. This is a serious obstacle in the way of utilizing first generation hybrids.

It is possible to overcome this handicap and still retain hybrid vigor at its maximum by crossing again two first generation hybrids. The plants then start from large well-nourished seeds produced on strong, vigorous plants; the seeds germinate more completely; the seedlings start more quickly and grow more rapidly from the start. Such a double cross differs widely in genetic construction from a single cross. In the latter all plants are exactly alike in their hereditary composition if their parental inbred strains have been reduced to complete uniformity and constancy. In a double cross, however, the plants are all genetically unlike to a greater or lesser degree; but individually they are all essentially first generation hybrids. Recombination allowing recessive weaknesses to appear is not possible and, from the standpoint of even size of plant and uniform production of ears, double crossed plants are equal to their single crossed parents and in vigor of growth and productiveness are clearly superior, as shown in Table 1.

Another advantage may be possessed by the double crosses in that being somewhat more variable they may be more adaptable to different seasonal conditions. All the plants of a single cross developing at the same time may be affected by unfavorable weather conditions at a critical time and in some seasons may be unduly injured, whereas in the case of the double cross, part of the plants may escape injury.

Whatever may be the explanation of the increased yields the results of three years tests show unmistakably that the double crosses have a decided advantage over both single crosses and varieties. In 1918, the first year any double crosses were grown, ninety-four plots, containing many different quadruple combinations of the inbred strains previously described, ranged in yield from 55 to 135 bushels per acre. Grown in the same field, one hundred and sixty-five variety plots yielded from 45 to 115 bushels per acre. The lower range in the variety yields can not be compared with the double crosses because some of the varieties matured earlier. But disregarding the lower yielding half of the distribution the remaining figures which represent varieties which matured as late or later than any of the crosses, fall far short of the results given by the hybrids. The mode of the latter is at 115 which is the upper limit of the distribution of the variety yields.

TABLE 1.—*A comparison in yield of inbred strains of corn and their single and double first generation hybrids with normally pollinated varieties.*

Class.	Year grown.	Bushels of shelled corn with 12 percent moisture per acre.														Number of strains.	Average yield.
		5	15	25	35	45	55	65	75	85	95	105	115	125	135		
Inbred strains	1916	11	23	14	12	4	..	..	..	..	..	...	...	...	...	64	21.1±1.0
Single crosses	1916	1	1	5	6	12	11	9	19	21	12	6	2	...	...	105	69.5±1.6
Varieties	1916	..	..	..	5	11	44	44	32	34	25	3	...	...	...	198	70.4± .8
Inbred strains	1917	..	1	9	8	10	3	..	..	..	..	...	...	...	...	31	36.6±1.4
Single crosses	1917	..	..	..	..	..	..	4	7	11	14	8	5	...	...	49	91.1±1.3
Varieties	1917	..	..	..	..	..	1	6	19	18	28	4	1	1	...	78	86.2± .9
Varieties × inbred	1917	..	..	..	..	..	..	..	1	7	7	6	1	...	...	22	94.5±1.4
Inbred strains	1918	..	1	8	5	2	4	1	..	..	..	...	...	...	...	21	36.4±2.0
Single crosses	1918	..	..	..	..	..	..	..	1	0	2	0	1	...	...	4	95.0
Double crosses	1918	..	..	..	..	..	1	3	6	12	13	23	24	9	3	94	102.8±1.2
Varieties	1918	..	..	..	..	1	22	44	41	31	21	4	1	...	...	165	74.9± .7
Inbred strains	1919	1	3	10	4	5	3	..	..	..	..	...	...	...	...	26	31.9±1.7
Single crosses	1919	..	..	..	1	1	4	9	15	29	6	1	...	...	...	66	78.0±1.0
Double crosses	1919	..	..	..	..	1	7	13	27	13	3	2	...	...	...	66	74.2±1.0
Varieties	1919	..	..	1	7	17	48	38	12	4	..	...	...	...	...	127	58.1± .7
Single crosses	1920	..	..	1	8	11	8	3	..	..	..	...	...	...	...	31	46.3±1.2
Double crosses	1920	..	..	8	25	45	64	45	30	1	..	...	...	...	...	218	54.5± .6
Varieties	1920	..	..	9	33	35	25	8	3	..	..	...	...	...	...	113	44.9± .7

The same higher distribution of the yields of the double crosses is seen in the results for 1919 and again but not so pronouncedly in 1920. In the last year all yields are low. Probably the fairest comparison that can be made is to consider the yields of the ten most productive double crosses with the ten highest yielding varieties during the three years as shown in Table 2. Here it will be

TABLE 2.— *The ten highest yielding double crosses compared with the ten highest yielding varieties during three years trial.*

(Expressed as bushels per acre.)

1918		1919		1920	
Double crosses.	Varieties.	Double crosses.	Varieties.	Double crosses.	Varieties.
117	96	96	79	84	59
116	93	94	79	76	57
109	92	93	75	76	57
109	92	91	75	74	55
105	89	91	72	74	55
101	89	90	71	72	54
99	86	88	71	71	53
99	86	88	67	70	52
97	86	88	67	70	51
93	85	85	64	69	51
104.5	89.4	90.4	72.0	73.6	54.4

Increase from double crosses.

1918	1919	1920
15.1 bu. per a.	18.4 bu. per a.	19.2 bu. per a.
16.9 percent	25.6 percent	35.3 percent

TABLE 3.— *The average yield of one double cross compared with the yields of two high producing varieties during three years.*

Class.	1918 Yield.	1918 No. plots.	1919 Yield.	1919 No. plots.	1920 Yield.	1920 No. plots.
Double crossed Burr-Leaming........	116	31	88	3	55	71
Highest yielding flint variety in 1918...	96	4	54	2	51	2
Highest yielding dent variety in 1918..	92	4	58	2	39	2

TABLE 4.— *Number of moldy ears shown by flint and dent varieties, single and double crosses and inbred strains as grown in 1919.*

Class.	Percent of moldy ears. 2	7	12	17	22	27	32	37	42	47	52	57	62	Number of strains	Average percent.
Flint varieties..	2	14	16	17	8	1	2	2	1	1	0	0	1	65	16.54± .89
Dent varieties.	12	27	15	1	1	..	..	..	..	..	..	..	..	56	7.71± .38
Single crosses..	23	18	7	3	0	0	1	..	..	..	..	..	..	52	6.52± .53
Double crosses.	22	11	9	2	2	..	..	..	..	..	..	..	..	46	6.67± .55
Inbred strains*	11	5	1	1	1	0	0	1	..	..	..	..	..	20	7.25±1.32

*One strain had all the ears slightly molded.

noted that the lowest of the ten crosses is higher than the highest yielding variety, except in 1918 where there is a difference of only

three bushels. The average increases of 16.9, 25.6 and 35.3 percent are certainly significant. Not only are the results as a whole noticeably in favor of the double crosses as compared with the varieties but particular combinations showed up well in each of the three years tested. In 1918, a quadruple combination of two inbred strains from Illinois High- and Low-Protein out of Burr's White with two inbred strains from Illinois Leaming was grown as a check thruout the variety plots. For convenience this particular combination has been called Double Crossed Burr-Leaming. These thirty-one check plots in all averaged 116.3 bushels. A slightly different combination, in which one inbred strain from Connecticut Leaming was substituted in place of one of the Burr White strains, was grown in twenty-six plots and these averaged 109.3 bushels. The highest yielding dent variety gave 92.3 bushels per acre and the highest flint 96.4 the same year, these variety yields being an average of four plots each.

In 1919, the same double crossed Burr-Leaming yielded 88.1 bushels. The highest dent variety produced 79.1 and the highest flint 79.0. These yields are based on an average of two plots for each of the varieties and three plots for the double cross. In 1920, the double crossed Burr-Leaming was again used as control and 71 plots in all averaged 54.8 bushels. This average yield was equalled or slightly exceeded by four varieties, two dents giving 54.8 and 56.6 and two flints giving 56.9 and 59.4. The variety yields represent an average of two plots each and have been corrected for soil differences by adding or subtracting the deviation in actual yield from the theoretical yield of the control, as calculated from the two adjacent check plots, to the average yield of all the check plots. The yields given above can therefore be compared fairly with each other with the reservation that the small number of plots of the varieties makes their results somewhat less reliable than that obtained from the large number of plots of the double cross.

In 1920, one double cross representing a new combination of two inbred flint with two inbred dent strains yielded 84.3 bushels which is 42 percent higher than the highest yielding variety grown that year. Moreover, twenty-four different double crosses, not counting check plots, yielded more than the highest yielding variety. In this comparison all yields are an average of two plots and have been corrected to the controls.

One other comparison remains to be made. From a consideration of the behavior of certain crosses and varieties thruout the three years, as shown in Table 3, it is evident that the yields of particular

crosses fluctuate from year to year in the same way as do individual varieties. The same relative position is held, however, during the three years. From the practical standpoint this is the most important comparison that can be made.

Examined in all possible ways, the results clearly indicate a superior yielding ability possessed by the double crosses. It would be more satisfactory if the inbred strains had all been derived from local varieties and only these varieties had been compared with the crosses. Since this was impossible it seemed to be the best plan to place all the crosses in competition with all the varieties grown. This is the test which all corn must meet before its actual value can be demonstrated.

In addition to the larger yields there has been an appreciable improvement in quality in many of the hybrids due to less moldy corn, fewer immature and poorly developed ears. Table 4 gives the results obtained in 1919 which, being very wet in the fall, was favorable for mold to develop. No significant differences are shown in the averages of all the plots between the crosses and the dent varieties, but the distributions of the data show that more of the crosses are in the class of lowest percent of mold. None of the varieties were entirely free from moldy corn whereas eight inbred strains, five single crosses and one double cross were. Most of the double crosses had certain inbred strains in their make-up which were notably subject to mold damage. Other crosses are noticeably free from injury. In 1918 the double crossed Burr-Leaming combination gave only two slightly moldy ears in the crop from more than 3,000 plants.

It is also expected that a real resistance to smut infection can be obtained together with high yield. Unfortunately many of our otherwise good inbred strains are badly affected by smut parasitism. The double crossed Burr-Leaming has two inbred parents which are regularly severely injured by smut, one showing as high as 73 percent of the plants attacked, during the past season. Contrasted with this is the fact that these same strains are notably free from external indications of root-rot infection. The plants stand upright thruout the season and their foliage stays green until the seeds are well ripened. The husks are quite green when the seeds are glazed and the ears are as a rule free from mold.

Even tho inbred strains when crossed do yield more than other kinds of corn it yet remains to be demonstrated that hybrid seed can be produced in sufficient quantity and at a low enough cost to be an important factor in corn growing. The most serious obstacle

in the way is the low production of the pure parental types so far obtained, when these are grown by themselves. Every effort should be made to find as high yielding inbred strains as is possible to secure and it may be questioned whether or not weak strains, even tho they give good results when crossed in particular combinations, should be saved for the purpose of producing hybrid seed. The value of such weak strains may be realized in some other way, as, for example, by crossing with other strains and again selecting or by entering into the composition of a new variety which has been purified by inbreeding. But effort should be directed toward obtaining inbred strains which are themselves vigorous and productive. With these secured the attainment of high yielding, high quality, dependable types of corn, adapted to particular places and purposes and possessing a measure of freedom from several diseases which now seriously injure corn, will be in sight.

LITERATURE CITED.

1. EAST, E. M. The distinction between development and heredity in inbreeding. *In* Amer. Naturalist, v. 43: 173–181. 1909.
2. EAST, E. M. and HAYES, H. K. Heterozygosis in evolution and in plant breeding. U. S. Dept. Agric., Bur. Plant Ind., Bul. 243. 1912.
3. ————, and JONES, D. F. Inbreeding and outbreeding: their genetic and sociological significance. 285 pp. Philadelphia; Lippincott Co. 1919.
4. ————, and JONES, D. F. Genetic studies on the protein content of maize. *In* Genetics, v. 5: 543–610. 1920.
5. JONES, D. F. Segregation of susceptibility to parasitism in maize. *In* Amer. Jour. Bot., v. 5: 295–300. 1918.
6. ————. The effects of inbreeding and crossbreeding upon development. Conn. Agr. Exp. Stat. Bul. 207. 1918.
7. ————, Selection in self-fertilized lines as the basis for corn improvement. *In* Jour. Amer. Soc. Agron., v. 12: 77–100. 1920.
8. Merriam, C. H. et al. Fourth provisional zone map of North American. U. S. Biological Survey, 1910.
9. Noll, C. F. Experiments with corn. Penn. Agr. Exp. Sta. Bul. 139. 1916.

AGRONOMIC AFFAIRS.

ACTIONS OF THE ADVISORY BOARD OF THE AMERICAN SOCIETY OF AGRONOMY TO THE NATIONAL RESEARCH COUNCIL.

At a meeting of the Advisory Board of the American Society of Agronomy held with the Chairman of the Division of Biology and Agriculture, Dr. L. R. Jones, at the National Research Council, December 10, 1921, to adjust matters in reference to the relation of the Advisory Board to the Research Council and particularly with the idea of taking over certain agronomic projects which developed

within the Research Council during the war period, Messrs. Lipman, Marbut, and Piper, of the Board, present, and Prof. A. G. McCall in consultation, the following actions were taken:

I.

The Advisory Board established four committees, of three members each, as follows:

a. Committee on Soils, to consist of
   Dr. C. F. Marbut, Bureau of Soils, Washington, D. C.
   Dr. F. J. Alway, College of Agriculture, St. Paul, Minn.
   Prof. S. D. Conner, Purdue University, La Fayette, Ind.

b. Committee on Fertilizers, to consist of
   Dr. J. G. Lipman, College of Agriculture, New Brunswick, N. J.
   Dr. F. E. Bear, College of Agriculture, Columbus, Ohio.
   Dr. B. L. Hartwell, Agricultural Experiment Station, Kingston, R. I.

c. Committee on Crops, to consist of
   Prof. C. V. Piper, Bureau of Plant Industry, Washington, D. C.
   Prof. C. A. Mooers, College of Agriculture, Knoxville, Tenn.
   Dr. C. A. Zavitz, College of Agriculture, Guelph, Ontario.

d. Committee on Plant Nutrition, to consist of
   Dr. A. G. McCall, College of Agriculture, College Park, Md.
   Dr. H. L. Shantz, Bureau of Plant Industry, Washington, D. C.
   Dr. Robert Stewart, College of Agriculture, Reno, Nevada.

It is the idea of the Advisory Board that each of these committees shall consider and recommend on all projects coming within its province.

II.

Each line of investigation recommended by the Board and adopted by the Research Council shall be called a *project*, to each of which shall be designated a *project-leader*. Including the war projects of the Division of Biology and Agriculture, and which have now been put under the direction of the Advisory Board, the projects now before the Research Council are as follows:

a. Assistance in financing the publication of the Journal of the American Society of Agronomy; under direct supervison of the Board.

b. Better coordination and cooperation in agronomic research; under the supervision of the Board.

c. Soil Research Institute; project leader, Dr. J. G. Lipman.

d. Monograph on lime; project leader, Dr. W. H. McIntire.

e. Monograph on history of soil development; project leader, Dr. C. F. Marbut.

f. Physiological soil requirements of plants; project leader, Dr. A. G. McCall.

g. Pasture investigations; under charge of the Committee on Crops.

III.

In connection with the above scheme of organization, the following resolutions were passed:

a. That the Advisory Board of the American Society of Agronomy accepts the sponsorship of the agronomy projects of the Research Council instituted during the war, and also the personnel of the existing committees, with the exception that the Committee on Fertilizers is reduced to three members.

b. In accordance with the new scheme of organization, the project leader for each project is to be approved by the Advisory Board on nominations presented by the committee directly concerned with the project. Associates on each project are nominated by the project leader, subject to approval by the responsible committee and the Advisory Board.

TEXAS BRANCH OF THE AMERICAN SOCIETY OF AGRONOMY

Members of the Society who live within easy access of each other, and are therefore able to unite in a similar enterprise, may be interested in the following statement with reference to the recently-organized Texas Branch of the Society, which has been received from J. H. McDonald, the Secretary-Treasurer of the Branch:

"As you requested in your recent letter, I am sending you a list of the members of the Texas Branch of the American Society of Agronomy. They are as follows:

Local Members

T. Hensarling, *President*	E. W. Handley
W. P. Patton, *Vice-President*	C. C. Jobson
J. H. McDonald, *Secretary-Treasurer*	B. J. Masuda
U. E. Christopher	J. C. Miller
J. C. Graham	C. Real
H. Govea	

Honorary Members

J. O. Morgan	A. B. Conner
C. A. Wood	E. B. Reynolds
E. P. Humbert	B. Youngblood
J. H. Stallings	A. H. Leidigh
D. G. Sturkie	E. W. Geyer
W. H. Corpening	A. K. Short

"Our society meets twice per month. It is the general plan to have on each program one outside speaker, and two or three student speeches. The outside speakers include the College professors, the Experiment Station and Extension Service men. Programs of special excellence have been held lately. Doctor E. P. Humbert, professor and plant breeder of wide experience, recently addressed the club on Commercial Plant Breeding. Doctor Tanquary of the Experiment Station spoke on Beekeeping in Texas.

"As can be seen from what I have said, we have rather diversified programs, thereby insuring greater interest.

"The Club recently voted favorably on the establishment of a National Grain Judging contest. Plans for an inspection trip are now being discussed. The purpose of such a trip would be to visit big commercial seed farms, some agricultural sub-stations, and successful farms. We believe that such a trip would be of great help to prospective farm managers, etc."

WESTERN AGRONOMIC CONFERENCE

The sixth annual conference of agronomists in the eleven western states was held at Pullman, Wash., and Moscow, Idaho, July 20 to 22, 1922. The programs on Thursday afternoon and Friday morning were presented at Washington State College and those on Friday afternoon and Saturday at the University of Idaho. Inspection of the agronomic experiments on the Washington and Idaho stations and an 80-mile automobile trip from Moscow to Lewiston, Idaho. and return, were a part of the program. The Lewiston trip covered 30 miles of wide-spreading wheat fields in the rich Palouse district and the wonderfully scenic 10-mile descent into the canyon of the Clearwater and Snake rivers, with its panorama of orchards and farm lands.

The attendance included representatives from six states and of the U. S. Department of Agriculture, the usual number present at the meetings being about 40. The program consisted of the papers named below. Most of the papers were followed by spirited discussion.

"Water Requirements as Influenced by Tillage Methods" by D. E. Stephens, Sherman Co. Branch Station, Moro, Ore. Discussion led by F. J. Sievers, of the Washington station.

"A New Method of Mechanical Analysis and its Application to the Study of Soil Structure" by M. D. Thomas, of the Utah station.

"Results of Different Crop Residues on Organic Matter Maintenance in the Soil" by Henry Holtz, of the Washington station.

"Control of Morning Glory in Cultivated Lands" by George Stewart of the Utah station (read by M. D. Thomas).

"Control of Smut by Copper Carbonate." Discussion by B. F. Dana of the Washington station and C. W. Hungerford of the Idaho station.

"The Place of Hybridization in Crop Improvement" by E. F. Gaines, of the Washington station. Discussion led by J. A. Clark of the U. S. Department of Agriculture.

"Sunflower Studies in Montana" by H. R. Sumner, of the Montana station (read by Clyde McKee). Discussion led by R. K. Bonnett, of the Idaho station.

"Dry-Land Forage Crops" by H. W. Hulbert, of the Idaho station. Discussion led by R. O. Westley, of the Washington station.

"Pasture under Irrigation" by Clyde McKee, of the Montana station.

"Standardization and Certification" by C. B. Ahlson, Idaho State Seed Commissioner. Discussion led by C. W. Warburton, U. S. Dept. of Agriculture.

"Response in Crop Plants to Environmental Conditions" by H. M. Wanser, of the Adams County Branch Station, Lind, Wash.

"How Does the 'Suggested Outline for Lectures in a Standard Introductory Course in Field Crops' Meet the Needs of the Western States?" by E. G. Schafer, of the Washington station.

The program also included informal talks by President Upham of the University of Idaho, Dean Johnson of the Washington college of agriculture, and Dean Iddings of the Idaho college. The committee to arrange for the next annual meeting, which is to be held at Bozeman, Mont., consists of Clyde McKee of the Montana station, E. G. Schafer of the Washington station, and C. W. Warburton of the U. S. Dept. of Agriculture.

NOTES AND NEWS

Dr. Eugene Davenport retired on September 1st, after thirty-seven years of service as Dean of the College of Agriculture and Director of the Agricultural Experiment Station at the University of Illinois; and Professor Herbert W. Mumford, who has been for more than twenty years the Chief of the Department of Animal Husbandry at Illinois, has been appointed as his successor.

Dr. Edward C. Elliot, formerly Chancellor of the University of Montana, has been appointed President of Purdue University, at Lafayette, Indiana.

Henry Dunleavy has transferred from Allen farm, Texas, to Robstown, Texas, where he will be in charge of cotton breeding for a commercial grower of Mebane cotton seed.

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PLOT COMPETITION WITH POTATOES.[1]

B. A. Brown.[2]

That there is much competition between adjacent plots in experimental work with many crops is an undisputed fact and considerable information has been published on this subject.

At the Storrs Station, competition between variety plots of soybeans and oats has been noted and a brief summary of the data is given here. In 1917, 25 single row check plots of soybeans averaged 26.9 bushels of seed per acre. The variety used as a check was a small, early-maturing one. When the check variety occurred between the varieties O'Kute and Swan or Mammoth Yellow and Mongol, all of which are much larger and later than the check, the latter averaged only 17.1 bushels of seed per acre or 63.6 percent as much as the average for all check plots. In the same series of plots were planted a few varieties of field beans, which were much less vigorous in growth than the soybeans and which matured 17 days before the check variety. The average for the four check plots of soybeans which were between two plots of filed beans was 38.4 bushels of seed per acre, or 142.7 percent of the average for all checks.

In 1919, a series of oat varieties were drilled solidly in 4 row (28 inch) plots, and the two outside rows of each plot were discarded at harvest. To obtain some measure as to the comparative yields of outside rows and the average of the two central rows, 10 outside rows from different plots were threshed and the grain and straw weighed. Although varying in the amount of increase, the outside rows averaged 73.2 bushels of grain and 3,802 pounds of straw as compared to 52.3 bushels of grain and 2,464 pounds of straw per acre for the average of the two central rows for the same 10 plots, or a 40 percent increase of grain and a 54.3 percent increase of straw.

[1] Published with the permission of the Director, Storrs Agricultural Experiment Station, Storrs, Conn. Received for publication, January 17, 1922.

[2] Assistant Agronomist.

Confronted with data from many stations with other crops and the results given above, the question arose whether there is competition between potatoes in the single row plots, 103.7 feet in length, which are used at Storrs for variety and strain testing. In these experiments, all potations have been planted with an Iron Age 2-man planter, set to drop seed pieces 12 inches apart, with rows 3 feet apart. A good stand of plants has been the rule. The fertilizer (4-8-4) has been applied through the planter at 1,500-2,000 pounds per acre, but always the same amount for the entire series of plots in any one year. "Medium ridge" cultivation and good spraying have been given.

Beginning in 1916 and through 1921, the same strain of Green Mountains has been used for the checks, which occurred every fifth plot, except in 1921, when they were every tenth plot. From the results of the six years, all the check plots, which had adjacent plots on either side with available yields were taken for this study. There were 137 such plots.

Although the natural producing ability of the soil varied considerably, it seems reasonable to suppose that plots on either side of the check would have practically the same conditions. Therefore, to find if the checks benefited by being between low yielding adjacent plots, the yield of each check was compared to the average yield of its two adjacents. If the checks did benefit by being between low yielding adjacents, than a negative correlation should result. However, a positive correlation of 0.271 ± 0.053 was found, which, while not enough greater than the error to warrant the conclusion that the yields of the checks increased with an increase of the yields of the adjacents, surely does not give any evidence of the reverse being true.

The conclusion is, therefore, that with conditions as stated above, yields of potatoes are not influenced by competition between single row plots.

AN INDEX FOR MEASURING THE PERFORMANCE OF WHEAT VARIETIES AND STRAINS.[1]

W. B. Kemp.[2]

Agricultural experiment stations are frequently confronted with the problem of measuring the progress that has been made in variety testing, selection, or breeding of wheat and other small grains. This is comparatively easy, as long as a large group of older varieties

[1] Contribution from the Maryland Agricultural Experiment Station, College Park, Md. Received for publication March 3, 1922.

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is retained without change for use as seed, because a new variety may always be compared with the average of the group. However, during many years of testing some of the older varieties are replaced by newer and apparently better ones; therefore, it is frequently difficult to make up such a group.

Experiment stations generally use check plots with which to compare the different varieties that are on test in any one year, but unfortunately they are not a reliable measure of changes that take place from one year to the next. This is true even when the same variety is used as check throughout a series of years. To illustrate this fact, the behavior of Currell's prolific and Fultz wheats are compared. The former was the check variety at the Maryland Station in 1889 and 1890; the latter has been used from 1891 to the present time. Table I shows a comparison of the yields of these two varieties together with the ratio of their yields.

TABLE I.— *Comparative yields of two varieties of wheats used as checks.*

	1891–'96	1897–1907	1908–'17	1918–'21
Fultz	36.6	30.9	25.15	17.33
Currell's	35.5	34.4	28.14	20.59
Ratio of Currell's to Fultz	0.970	1.113	1.158	1.190

The significant fact brought out by these figures is that although Fultz outyielded Currell's in the early years of testing, later Currell's outyielded Fultz and continued to increase in superiority. For some years, the Currell's variety was subjected to much mass selection and this, with the later gradual reestablishment of equilibrium, may account for the improvement in this variety. Or, Fultz may do relatively better when yields are high, as they were when wheat followed cowpeas, for the higher production of all varieties in earlier years may be accounted for by differences in the rotation. Then wheat generally followed cowpeas; later it frequently followed wheat, while now it always follows corn — a custom that was adopted because the greater proportion of Maryland wheat is planted on corn stubble.

Another peculiarity that makes it difficult to use a single variety as a basis for comparisons is illustrated by the behavior of Fultz, mammoth red, and China for the fourteen years since the last two were put on test. A study of the comparative yields of these varieties for the different years during this period shows that in years when the average wheat yields on the station plots ranged from 16 to 22 bushels per acre, Mammoth Red yielded 25.67 bushels, or 131.7 percent of average; China, 22.45, or 114.7 percent; and Fultz, 16.37, or 83.4 percent. But in years when average yields

ranged from 22 to 34 bushels, Mammoth Red averaged 29.20, or 104.2 percent; China, 30.93, or 111.4 percent; and Fultz, 27.46, or 99.4 percent. Or expressed in another way; in unfavorable wheat years when average varieties yielded 8.17 bushels less than the average for the entire period, Mammoth Red fell below the average by 3.53 bushels; China by 8.48; and Fultz by 11.09. In unfavorable years, Mammoth Red was much less affected and Fultz much more so than are average varieties; while China showed just about the average diminution in yield. It is evident that China would more nearly fulfill the requirements for a check variety than would either of the others; but as a measuring stick, even it leaves much to be desired.

In an effort to establish an index that will measure the progress from year to year, it immediately becomes apparent that consideration of the average behavior of as many varieties as possible is necessary before the environmental effect between any two successive years can be measured. Thus, if 35 varieties are put on test, of which 30 are carried for two or more years and 5 are replaced by new ones the second year, and if the 30 original varieties make an average yield of 20 bushels per acre in one year and 25 bushels in the following year, this difference of 5 bushels or of 25 percent must be corrected before any change can be recorded for the test as a whole. If in the first year, the average yield of all 35 varieties on test was 19 bushels and in the second year 26, the change in yield brought about by the substitution of the 5 varieties may be found by using the following proportion — 20 (the yield during the first year of the 30 varieties on test both years) : 19 (the yield of all 35 varieties) ::25 (the yield of the same 30 varieties in the second year) : (the yield that all 35 varieties would have produced in the second year if they had been continued). By calculation this would be found to be 23.75. But the actual yield in the second year was 26.0 bushels. The substitution of the 5 new varieties, therefore, caused an increase in average yield of 2.25 bushels — a figure that should be correct except for variation in seasonal response of different varieties, and these variations should tend to counteract each other. The 23.75 bushels is the base from which the index of any variety for that year is calculated and is given a value of 100. The 26 bushel yield would thus have a value of 109.5. This is calculated as follows: 23.75:26::100:109.5. Taking similar data from table 2 for the years 1913 and 1914, the following results are obtained, 22.32:34.27::19.57:X or 34.04. 30.04:33.56:: 100 : 112.

The size of the base for any particular series of tests depends upon the group of varieties that by chance or design were included in the first year's trial. Therefore, the index for one series does not necessarily bear any relation to that for another, unless the other series had the same varieties on test in its first year. But the ratio between different series of indices is always comparable. If any one variety has remained on test for a number of years its average index for different periods should, on the whole, remain constant, except where cyclic seasonal conditions have produced cyclic responses.

To determine the validity of an index established as above, separate averages were obtained for the first and second halves ot its test period for each variety that remained on trial for eight or more years. These averages brought out the fact that the index for most varieties had a tendency to slowly rise. A small cumulative error could cause such a result, and two of these were finally located. A study of the indices of eighty-seven varieties that had not been dropped until they had been on test for three or more years showed that they came in at 145.9, but in their second year made only 143.9. The tendency to drop, after one year, those varieties with very low yields had eliminated the lowermost varieties of a normal frequency distribution, and had advanced the mean by two points. The eighty-seven varieties were dropped from test on an average index of 145.2; although in the year before their last they had scored 150.9. This fact revealed a tendency to drop a variety after a very poor year for that variety, instead of dropping it after a normal year. An error of 5.7 resulted from this tendency. Both of these errors were eliminated by removing from consideration any variety that was carried for less than three years, and figures for the first and last years were dropped from all varieties that were used to establish the final index.

The present figure shows no tendency for average varieties to either advance or decline, but there are a few varities whose index is apparently advancing, while that for others is becoming smaller. A plausible theory to account for these variations assumes that by crossing or mutation a biotype has appeared within the variety and is gradually gaining the ascendency. Or, perhaps, one already present in a variety new to the section is favorably affected by its change of residence. If this biotype is an inferior one, with small seed or with an overtopping growth, a descending index will result. In most cases, however, only a superior one can gain the ascendency, and with its gain will come an ascending index.

TABLE 2.—*Indices for thirty years of wheat variety tests at College Park, Maryland.*

1	2	3	4	5	6	7	8	9	10	11
Year.	Varieties on test.		Varieties from former years.		Varieties in following year.		Yield if all on test were the twelve of 1890.	Index for all on test.	Index for	
	Number.	Yield.	Number.	Yield.	Number.	Yield.			Fultz.	Mammoth Red.
1890	44	10.80	......	....	12	13.01	13.01	83	....	....
1891	19	13.30	12	13.34	12	13.34	13.34	100	160	....
1893	31	33.56	12	32.70	12	36.07	32.70	103	144	....
1894	40	34.50	12	39.44	18	39.45	35.76	96	116	....
1895	22	35.98	18	35.64	20	35.94	32.30	111	113	....
1896	23	34.01	20	33.60	21	33.72	30.20	112	115	....
1897	23	37.60	21	37.87	5	38.54	33.91	114	129	....
1898	25	27.30	5	33.00	5	33.00	29.03	94	88	....
1899	5	32.18	5	32.18	5	32.18	28.31	114	120	....
1900	9	38.20	5	39.50	5	39.50	34.75	110	119	....
1902	12	26.00	5	28.14	8	28.95	24.75	105	120	....
1903	11	17.20	8	19.56	10	18.13	16.72	103	93	....
1904	10	25.88	10	25.88	10	25.88	23.87	108	85	....
1905	11	27.95	10	27.93	8	29.53	25.77	109	116	....
1906	11	25.30	8	25.96	6	26.33	22.62	112	112	....
1907	9	37.90	6	39.73	5	40.12	34.18	111	122	....
1908	78	29.01	5	32.03	5	32.03	27.28	106	113	116
1909	60	19.13	5	21.58	48	19.92	18.38	104	96	148
1910	56	28.09	48	28.98	40	29.03	26.74	105	111	105
1911	57	32.08	40	32.85	29	33.13	30.24	106	104	112
1912	53	21.56	29	35.00	35	23.38	21.16	102	82	140
1913	41	21.37	35	21.63	23	22.32	19.57	109	102	134
1914	42	33.56	23	34.27	21	34.70	30.04	112	101	122
1915	27	22.53	21	23.16	17	23.33	20.05	112	119	109
1916	23	24.95	17	25.41	16	25.84	21.83	114	115	113
1917	18	23.69	16	24.00	17	23.93	20.27	117	108	122

TABLE 2 — *Continued.*

1918	25	19.12	17	19.50	13	19.70	16.31	116	101	140
1919	25	19.28	13	19.92	13	20.06	16.69	116	94	151
1920	21	27.54	13	27.90	13	27.90	23.21	119	114	136
1921	13	16 60	13	16.61	......	....	13.81	120	77	162

The 12 varieties in column 6 in 1890 are the same as those in column 4 for 1891, and so on for all years.

Columns 10 and 11 are added to show the contrast in behavior. Note that in any year when Fultz made an index of less than 100, Mammoth Red scored 140 or more.

Average index of 1890	83
Average index of all varieties in 1890 that were retained for three or more years	100
Best five varieties that were on test in early years	114
Best five now on test	126
Best variety now on test	129

Since the index removes from consideration any change that takes place within average varieties while they are on test, all advances and declines are merely relative. To get an actual measure of this, it is apparently necessary to take seed of two or more varieties, one with an ascending, another with a descending index. A part of this seed should be planted in the regular variety test, the remainder should be saved through as many years as it will retain vitality. It should then be planted, and the seed again divided into two parts — one part to be saved as before, while the other is planted beside seed of the same variety that has remained on test each year. This process ought to be continued until it is possible to determine from the ever-widening gap that may appear between the two indices for each variety, whether the advances and declines are actual or merely relative. For, if seed from deferred generations should have an index becoming gradually higher than the normal one, it is an indication that varieties have a tendency to slowly decline in yield, or to "run out." Such a tendency, if it applies to most varieties, can not be seen from the index and can be determined only by such a test.

Some of the many uses of an index such as the one here described may now be pointed out. By its use, the yielding power of standard varieties today may be compared with the power of the same varieties, and of others, years ago. The comparative responses of different varieties to soil and to season may be learned and analyzed, and the information so obtained may act as a valuable guide in selecting parents for crosses.

As an indication of the first use, the data presented in table 2, column 9, show that the average yielding ability of all varieties on test has advanced from 83 in 1890 to 120 in 1921. But many of the early varieties were dropped after one year's trial, or before they could demonstrate their true worth, so that 100 (the yield of all that were carried for three or more years) may be considered as the original base. The five best varieties that have been carried for ten or more years and are still on test have an average index of 126. Their seed has been widely distributed over the state, and the best figures obtainable indicate that about 70 percent of the wheat acreage in Maryland is now planted to these varieties.

Work by Metzger and Sando at this Station indicates that high rainfall in March and in May generally causes low wheat yields. A correlation of $+.839 \pm .053$ exists between the combined rainfall of March and May and the yearly indices of the Mammoth Red variety. This indicates that high rainfall in these months affects Mammoth Red much less than average varieties. A correlation of $-.632 \pm .108$ for Fultz shows that this variety is very seriously

affected. In Table 2, column 10, it will be observed that, as a whole, the indices for Fultz have remained fairly constant for the past twenty-nine years. Yet in some cases they have been markedly affected by such unfavorable years. During this period the actual yields have varied so much that a study of them can not bring out these facts as the indices can.

The third use for this index is strikingly illustrated in Table 3. The average yields of wheat in 1921, 1918, 1909, 1919, 1913, and 1912, were such that they may be considered as poor wheat years, while other years since 1907 may be considered as good. (1917 is omitted because some of the leading varieties were not on test in that year.)

TABLE 3.— *Comparison of indices for six varieties of wheat during poor years and good years.*

	Bearded purple straw.	Dietz long-berry.	Turkish amber.	Mammoth Red.	China.	Currell's prolific.
Average index for poor years......	136.3	124.5	132.5	145.9	126.9	114.3
For good years....	119.1	121.0	118.7	117.1	123.1	124.4

In the poor years, Mammoth Red yielded better than any other variety on test; while in good years Currell's prolific has done best. Unless factors that can not be combined in one individual, such as difference in time of ripening, are responsible for this condition, it is reasonable to expect that among the progeny of a cross between Mammoth Red and Currell's prolific a type may be selected that approaches 145.9 in poor years and 124.4 in good ones.

But an even more striking contrast is found among the pure-line selections from these varieties. For four years, 2,008–4–12, selected from Mammoth Red, has been planted beside its parent. In 1915 and 1916, when the parent showed an average index of 111, the selected strain showed an index of 115, an advance of 4 points. In 1920 and 1921, when the average index of the parent was 149, the index of this selection was 165.5, an advance of 16.5 points. Thus the apparent tendency of this selection is to exaggerate the peculiarity of its parent. Further, 89–16–14, from Currell's prolific, has been planted for the past two years beside the variety from which it was selected. In 1921, when Currell's scored 90.8, the selected strain as an average of duplicate comparisons, scored 86.5, a loss of 3.5 points. In 1920, when the index of the parent was 127, this selection scored 131.7, or a gain of 4.7 points. Here again is a selection with a tendency to exaggerate the peculiarity of its parent. If these two continue to behave as they have done, may not a cross between them have even greater possibilities than a cross between unselected Mammoth Red and Currell's prolific?

BORDER EFFECT AND WAYS OF AVOIDING IT.[1]

A. C. Arny.[2]

In 1917 and 1918, when the extent of border effect for spring-sown oats, wheat and barley was determined (1, 2) it was noted that winter wheat, growing under similar conditions, appeared to have more marked border effect than the spring grains.

In 1921, the border effect in winter grains was as marked as usual and its extent was determined for a limited number of varieties. These data, considered in connection with that secured in previous years, extend the information over another year and to an additional crop.

Since border effect has been shown to be a factor in the reliability of plot tests, possible methods of preventing its occurrence and hence obviating the necessity and consequent expense of the removal of marginal areas have been of interest.

Growing varieties in contiguous plots without the intervention of alleys is open to several objections. Inability to distinguish exactly where one plot leaves off and the other begins when contiguous varieties are similar, and the practical impossibility of maintaining varieties pure, are mechanical difficulties. However, the more serious objection is the possible effect of one variety on another (3, 4, 5, 6)[3] when grown in this way, particularly since any one variety is flanked on either side by different varieties. Sowing the variety plots without the intervention of alleys, therefore, does not obviate the necessity of the removal of border rows.

The use of spring sown winter wheat on either side of each plot of spring-sown grain has been mentioned in this connection (7). Employing this method provides a uniform border which is in effect a cropped alley for all varieties in a test and in that respect is similar to the use of uncropped alleys. However, there is the possibility of the variety of winter wheat used in the cropped alleys reacting differently on the different varieties in a test. This effect might possibly be obviated to some extent by using seed of a number of winter wheat varieties composited instead of that of one variety only.

While the results of previous work appeared to make the efficiency

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[3] Reference by number is to "Literature Cited," p. 278.

of this method somewhat doubtful (6, 7), it seemed desirable to try it out carefully. This was done during the past season and the results form the main basis for this article.

TECHNIC OF THE EXPERIMENT.

All determinations of yields were made from plots located on University farm. The soil is a Hempstead silt loam not representative of any large section of the state. However, previous work (1, 2, 3) indicates that border effect on various types of soil approximating each other in productivity varies according to climatic condiditions and effects of previous cropping.

The winter wheat varieties were sown September first, 1920, in plots made up of 16 six-inch drill rows each, a total width of eight feet. There were four plots of each variety. The length after the ends had been trimmed off square was 130 feet. Each two plots were separated by an uncropped space or alley 18 inches in width. There were four plots each of the spring wheat varieties and three each of the oat and barley varieties. Each plot of the spring grains was made up of 12 six-inch drill rows of oats, wheat or barley bordered on either side by 2 six-inch drill rows of winter wheat, and was 130 feet long. The winter wheat on either side of each plot was sown at the same time as the spring grains so that it would not be handicapped in its competition with them because of later seeding. For convenience in seeding, tight fitting removable partitions of tin were placed in the drill box to separate off the outer two drill cups on either end. The two outer compartments thus separated off were kept filled with Minturki winter wheat at all times when the spring grain varieties were being sown. This winter wheat at first made about the same progress as the spring grains but the plants were more procumbent and did not joint. The winter wheat in the cropped alleys consequently was not in the way at harvest time.

There was approximately an 18-inch space between the outside drill rows of adjacent plots of winter wheat. Three inches of this space on either side belonged to the plot adjacent to it. This left a 12-inch uncropped space between adjacent plots.

In the spring grains, there was a space approximately twenty-four inches wide between the outer drill rows of adjacent plots occupied by four 6-inch rows of winter wheat.

Weeds grew both in the unoccupied alleys between each two plots of winter wheat and in the areas between each two plots of spring grain occupied by the four drill rows of winter wheat. The largest of these were removed by hand.

From the plots of the winter wheat varieties, three drill rows on either side were separately removed by hand at harvest, bound and tagged. In the spring grains, the winter wheat rows between plots were disregarded and three rows of the spring grain removed from either side of each plot in the same manner as from the winter wheat. These rows are referred to as outside, middle and inside border rows respectively.

The remaining ten drill rows in the winter wheat varieties and the six rows in the spring grain varieties were harvested with the binder. The oat and barley varieties were lodged and hence there was more or less loss in harvesting the central rows with the binder. Since the border rows were cut by hand, practically no loss occurred in the harvesting operation. This difference in method of harvesting the portions of the plots accounts to some extent for the difference in yields between the inside border rows and the average for the central rows for the oats and barley crops. In the wheat variety plots both winter and spring there was practically no loss in harvesting the central rows with the binder.

The entire product from each portion of each plot harvested separately was weighed and threshed with a small machine.

The straw weights for the most part paralleled the grain weights and therefore are not given in the tables which are presented in this paper.

The grain yields were computed for each area harvested separately. Each border row occupied an area 6 inches by 130 feet or 1/670.15 acre. The central areas in the winter wheat varieties were 10 drill rows or 5 feet wide and 130 feet in length of 1/67.015 of an acre in size. In the spring grain varieties, the central areas were 6 drill rows wide or 3 feet by 130 feet long or 1/101.68 of an acre in size.

After the yields for each portion of each plot had been computed separately, the necessary computations were made to secure the yields with none, one, two and three border rows removed, respectively. This was done by adding together the weights in pounds from all portions of each individual plot to show the weight with no border rows removed. The weight in pounds of the two middle and the two inside border rows added to that from the central rows gave the product with one border row removed from either side. The yields with two border rows removed were secured in a similar manner.

The standard deviations and probable errors were computed in the usual manner. All computations have been checked.

THE EFFECT OF UNCROPPED AND CROPPED ALLEYS ON THE YIELDS OF DIFFERENT PORTIONS OF PLOTS.

The plants in the border rows of the winter wheat varieties separated by uncropped alleys appeared darker green and slightly taller than those within the plots during late October of 1920; and in the spring when growth had well started, the same effect was noticeable, becoming more marked at jointing and heading time. At no time during the growing period was border effect plainly visible on the plots of spring grains flanked by alleys cropped to winter wheat. The border rows were not appreciably taller than the others and appeared to be no later in maturity. Counts of the numbers of culms per unit of row for the various portions of the same plots would probably have given an indication of what might be expected; but these were not made. Observations were made on nearby spring-sown plots of oats, wheat and barley separated by uncropped alleys and from jointing time on these were found to have the border effect more or less plainly visible. Much the same effect was noted on plots at the various substations and various outlying experimental fields in the state.

The yields for the different portions of both the winter wheat varieties separated by uncropped alleys and the spring grain varieties separated by alleys cropped to winter wheat together with percentage increases based on the yields of the central rows are given in Table 1.

The data for 1918 and 1917 are included in the table to facilitate comparison of results for the three seasons.

An examination of the yields of the various portions of the winter wheat plots shows that the outside border rows yielded at the rate of 33.67 bushels, the central rows at the rate of 18.86 bushels and the inside rows at the rate of 14.92 bushels, as compared with the yield of 15.95 bushels for the central rows.

In percent, the outside border rows yielded 211.1, the middle border rows 118.2, and the inside border rows 93.5 of the yield of the central rows. Comparison of these percentages with those for the same portions of the spring wheat plots in 1918 and 1917 shows a striking similarity, when the fact is taken into consideration that the determinations were made in different seasons and that one is a winter grain and the other a spring grain.

Bearing in mind the fact that the alleys between plots in the spring-sown oats, wheat and barley were occupied by spring-sown winter wheat, it is of considerable interest to note that for each of the three crops the outside and middle border rows show considerably higher yields than the inside border rows or the central

TABLE 1.—*Average yields in bushels per acre of varieties of oats, spring wheat, barley, and winter wheat harvested from border drill rows, spaced 6 inches apart, removed from either side of each plot, bordered by spring-sown winter wheat in 1920 and flanked by alleys only in 1918 and 1917. Also the yields from the central rows remaining after the removal of the border rows, and the yields of the border rows in percentages based on the yields of the central rows.*

Year and source.	Oats.			Spring wheat.			Barley.			Winter wheat.		
	Number of rows or plots.	Average yield per acre.		Number of rows or plots.	Average yield per acre.		Number of rows or plots.	Average yield per acre.		Number of rows or plots.	Average yield per acre.	
		Bushels.	*Percent.*		*Bushels.*	*Percent.*		*Bushels.*	*Percent.*		*Bushels.*	*Percent.*
1921:												
Outside border rows.....	24	65.58	199.9	32	30.56	153.6	24	48.93	213.5	26	33.67	211.1
Middle border rows......	24	58.53	170.4	32	25.75	127.4	24	42.74	186.5	26	18.86	118.2
Inside border rows.......	24	49.95	152.3	32	22.23	111.7	24	33.56	146.4	26	14.92	92.5
Central rows............	12	32.80	100.0	16	19.90	100.0	12	22.92	100.0	13	15.95	100.0
1918:												
Outside border rows.....	112	142.80	189.4	56	73.10	208.9	72	99.90	194.4	......	......	......
Middle border rows......	112	82.80	109.8	56	40.80	116.6	72	60.90	118.5	......	......	......
Inside border rows.......	112	80.00	106.1	56	39.80	113.7	72	55.80	108.6	......	......	......
Central rows............	56	75.40	100.0	28	35.00	100.0	36	51.40	100.0	......	......	......
1917:												
Outside border rows.....	88	131.97	184.9	40	55.00	204.4	32	97.73	238.0	......	......	......
Inside border rows.......	88	87.95	123.2	40	40.98	149.3	32	64.56	150.3	......	......	......
Central rows............	44	71.37	100.0	20	27.25	100.0	16	42.87	100.0	......	......	......

rows. The data for the yields from the outside border rows of the plots, expressed in percent based on the yields of the central rows, are 199.9 for the oats, 153.6 for the wheat and 213.5 for the barley as compared with 100 for the inside rows. These comparative yields indicate that the rows of winter wheat in the alleys *did* not prevent border effect.

The increases in yields due to border effect, expressed in percent based on the yields of the central rows, are for the outside rows 199.9 for the oats, 153.6 for the wheat and 213.5 for the barley and the middle rows in same same order 170.4, 127.4 and 186.5 respectively. The border effect on the wheat appears to be relatively lower than for the other crops; but this difference is not a real one. The border effect on the oats and barley, as indicated by the yields is somewhat higher than it should be due to the unavoidable loss of grain in harvesting the lodged central rows of these crops with the binder. The results, although somewhat lower for wheat, are similar to the results for the same crops in 1918 and 1917.

Based on yields of the central rows, the three-year average of the outside border rows, expressed in percent, for all crops is 199.8 and for the middle border rows (inside rows of 1917) it is 138.02. The outside border rows, therefore, averaged for the three-year period double the yield of the central rows and the middle border rows averaged for the same period over one-third more than the central rows.

BORDER EFFECT AND THE INTERPRETATION OF YIELDS.

In the former articles (1,2) attention was called to the fact that border effect due to alleys not only increases the yields of plots, the amount of increase depending on the size and shape of the areas used, but also may change the rank of varieties or rates of seeding in tests of that nature.

From the data given in Table 1 it is evident that spring-sown winter wheat growing in the alleys between each two plots of spring grains did not obviate border effect. Therefore, it appears desirable to use the 1921 data in determining the increases in yields from plots due to border effect on (a) each of the three border rows on either side of each plot separately, (b) on the outside and middle border rows combined, and (c) on the outside, middle and inside rows combined for spring and winter wheat. The data for the 1921 crop together with the data for 1918 and 1917 crops make possible the comparison of results for a three-year period. The increases in yields for the three-year period expressed in bushels and in percent are given in Table 2.

TABLE 2.— *Comparison of the increases in yields expressed in bushels per acre and in percents from plots of oats, wheat, and barley due to marginal effect on the outside, middle, and inside border rows on either side of each plot, the increases on the outside and middle rows combined, and the increases on the outside rows.*

Crop	Number of border rows removed from either side of each plot.	1921. Yield per acre.	1921. Increase in yields from plots due to border effect on the rows as follows: Outside rows.	1921. a. Outside and middle. b. Middle rows.	1921. a. Three rows. b. Middle and inside rows. c. Inside rows.	1918. Yield per acre	1918. Increase in yields from plots due to border effect on the rows as follows: Outside rows.	1918. a. Outside and middle. b. Middle rows.	1918. a. Three rows. b. Middle and inside rows. c. Inside rows.	1917. Yield per acre.	1917. Increase in yields from plots due to border effect on rows as follows: Outside rows.	1917. a. Outside and middle rows. b. Middle rows.
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Oats...........	None	46.31	......	....	....	83.4	......	....	....	80.5	......	....
	One	42.05	4.26	a8.84	....	75.9	7.5	a8.2	a9.1	73.6	6.9	a9.1
	Two	37.47	......	b4.58	....	75.2	......	b0.7	b1.6	71.4	......	b2.2
	Three	32.80	......	....	....	74.3	......	....	c0.9	....	......	....
			Percent.	*Percent.*	*Percent.*		*Percent.*	*Percent.*	*Percent.*		*Percent.*	*Percent.*
	One	......	10.13	a23.59	....	....	9.87	a10.90	a12.25	....	9.38	a12.74
	Two	......	......	b12.22	....	....	......	b 0.93	b 2.15	....	......	b 3.08
	Three	......	......	....	....	....	......	....	c 1.20	....	......	....
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Spring wheat....	None	23.46	......	....	....	40.8	......	....	....	32.5	......	....
	One	21.86	1.60	a2.81	a3.56	36.4	4.4	a5.0	a5.7	29.2	3.3	a5.21
	Two	20.65	......	b1.21	b1.96	35.8	......	b0.6	b1.3	27.3	......	b1.90
	Three	19.90	......	....	c0.75	35.1	......	....	c0.7	....	......	....
			Percent.	*Percent.*	*Percent.*		*Percent.*	*Percent.*	*Percent.*		*Percent.*	*Percent.*
	One	......	7.32	a13.61	a17.89	....	12.09	a13.97	a16.24	....	11.30	a19.05
	Two	......	......	b 5.86	b 9.85	....	......	b 1.68	b 3.70	....	......	b 6.96
	Three	......	......	....	c 3.77	....	......	....	c 1.99	....	......	....

TABLE 2 — *continued.*

		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Barley	None	33.04	......	......	......	58.3	......	......	......	51.4	......	......
	One	29.28	3.76	a7.24	......	53.2	5.1	a6.3	a6.9	45.8	5.6	a8.5
	Two	25.80	......	b3.48	......	52.0	......	b1.2	b1.8	42.9	......	b2.9
	Three	22.92	......	......	......	51.4	......	......	c0.6	....	......	......
			Percent.	*Percent.*	*Percent.*		*Percent.*	*Percent.*	*Percent.*		*Percent.*	*Percent.*
	One	......	12.84	a28.06	......	....	9.59	a12.12	a13.42	....	12.23	a19.81
	Two	......	......	b13.49	......	....	......	b 2.31	b 3.50	....	......	b 6.76
	Three	......	......	......	......	....	......	......	c 1.17	....	......	......
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Winter wheat	None	18.84	......	......	......	....	......	......	......	....	......	......
	One	16.45	2.39	a2.95	a2.89	....	......	......	......	....	......	......
	Two	15.89	......	b0.56	b0.50	....	......	......	......	....	......	......
	Three	15.95	......	......	......	....	......	......	......	....	......	......
			Percent.	*Percent.*	*Percent.*		*Percent.*	*Percent.*	*Percent.*		*Percent.*	*Percent.*
	One	......	14.53	a18.56	a11.85	....	......	......	......	....	......	......
	Two	......	......	b 3.52	b 3.13	....	......	......	......	....	......	......
	Three	......	......	......	......	....	......	......	......	....	......	......

TABLE 3.— *Summary of the increases in yields from plots due to border effect.*

Crop.	Increases in yields expressed in percent due to border effect on outside rows only.				Increases in yields expressed in percent due to border effect on outside and middle rows combined.				Increases in yields expressed in percent due to border effect on three border rows on either side of each plot.	
	1921.	1918.	1917.	3-year average.	1921.	1918.	1917.	3-year average.	1921.	1918.
Oats	10.13	9.90	9.40	9.81	23.60	10.90	12.70	15.73	....	12.30
Spring wheat	7.32	12.09	11.30	10.24	13.61	13.97	19.05	15.54	17.89	16.24
Barley	12.84	9.59	12.23	11.55	28.02	12.12	19.81	19.98	....	13.42
Winter wheat	14.53	......	......	......	18.56	......	......	......	....	....
Average for all crops				10.93				17.23		

A summary of the increases in yields of the plots due to border effect on the marginal areas, expressed in percent, is presented in Table 3.

The percentages of increase for the plots due to border effect on the outside rows, with the exception of that for spring wheat in 1921, are rather uniform for the three-year period, the mean being 10.96 per cent.

For the outside and the middle rows combined, the percentages of increases for the oats and barley in 1921 is rather high in comparison with the same results for the other two years. The mean for all of the determinations for the three-year period is 17.23 percent.

Data regarding border effect on three border rows on either side of each plot is available for only two years. The results for oats and barley in 1921 are not comparable with the others and therefore no average is taken. Under ordinary conditions it appears that the amount of border effect on the third row on either side of each plot is not a serious consideration. The yield of each variety, as determined from yields from plots of full size and with one, two, and three border rows removed from either side of each plot is given in Table 4. The varieties of each crop are first listed in order of yield as determined from plots from which no border rows were removed. The yield for each variety is then given with one, two, and three border rows removed.

In order to make comparisons of the value of the several varieties of each crop by each of the four methods of test, i. e., with none, one, two, and three border rows removed from either side of each plot, it is convenient to establish a discard point for the season. This has been accomplished by employing the formula

$$\frac{\text{Standard deviation x .6745}}{\sqrt{n}}$$

to derive the probable error for each test. In the formula, n represents the number of replicates of each variety. After the probable error for the four methods of test had been derived for the different crops, each was multiplied by the factor 3.8 which gives odds of 30 to 1 (8) against a difference between any two varieties being due to normal variation. This gives differences in bushels for none, one, two, and three border rows for each crop as follows: Oats, 4.98, 4.51, 4.90, and 5.89; spring wheat, 1.71, 2.05, 2.58, and 3.00; barley, 3.42, 2.81, 2.39, and 3.12; winter wheat, 1.21, 1.75, 1.63, 1.37, respectively. The figure obtained for each crop and method of test has been subtracted from the highest yielder and a line drawn indicating the discard point for the season under each method of test.

TABLE 4.—*Comparison of average yields per acre, in 1921, for three 1/55-acre plots (approximate size) of four varieties of oats and barley, and four plots of the same size of four varieties of spring and winter wheat with no border rows removed, and with one, two, and three border rows removed from either side of each plot.*

Crop and variety.	Number.	Descriptive note.	No border rows removed.			One border row removed.			Two border rows removed			Three border rows removed.		
			Yield per acre.	Standard deviation.	Rank.	Yield per acre.	Standard deviation.	Rank.	Yield per acre.	Standard deviation.	Rank.	Yield per acre.	Standard deviation.	Rank.
OATS		Time of maturity:	*Bu.*			*Bu.*			*Bu.*			*Bu.*		
Sixty Day [1]	674	Early	50.67	2.26 ± 0.62	1	46.00	1.48 ± 0.41	1	41.36	1.39 ± 0.38	1	36.10	1.71 ± 0.47	2
Minota [1]	512	Medium early	[2] *47.30*	7.66 ± 2.11	2	[2] *44.03*	6.10 ± 1.68	2	[2] *40.14*	6.10 ± 1.68	2	[2] *37.54*	5.62 ± 1.55	1
Victory	514	Medium	44.12	4.31 ± 1.19	3	38.71	3.91 ± 1.08	4	33.51	4.00 ± 1.10	4	28.00	4.15 ± 1.14	4
Iowa 103	531	Early	43.14	1.30 ± 0.36	4	39.46	2.31 ± 0.64	3	34.88	3.75 ± 1.03	3	29.56	6.87 ± 1.89	3
Average	.....	.....	46.31	3.88 ±	.....	42.05	3.45 ±	.....	37.47	3.81 ±	.....	32.80	4.59 ±	.....
SPRING WHEAT		Type:												
Marquis	1239	*vulgare*	24.83	1.07 ± 0.25	1	23.10	1.48 ± 0.35	2	21.91	1.68 ± 0.40	2	21.46	1.88 ± 0.45	1
Arnautka	2103	Durum	[2] *24.69*	.81 ± 0.19	2	[2] *23.21*	.69 ± 0.17	1	[2] *21.98*	1.07 ± 0.25	1	[2] *21.12*	1.27 ± 0.30	2
Preston	924	*vulgare*	22.95	2.73 ± 0.65	3	20.53	3.26 ± 0.78	4	18.98	4.10 ± 0.98	4	17.29	4.87 ± 1.16	4
Spring Emmer	1165	*dicoccum*	21.35	.71 ± 0.17	4	20.59	.94 ± 0.22	3	19.72	1.28 ± 0.30	3	19.71	1.36 ± 0.33	3
Average	.....	.....	23.46	1.33 ±	.....	21.86	1.59 ±	.....	20.65	2.03 ±	.....	19.90	2.35 ±	.....
BARLEY		Type:												
Minsturdi [1]	439	True 6-row	[2] *43.32*	3.15 ± 0.87	1	[2] *40.54*	2.48 ± 0.68	1	[2] *36.05*	2.83 ± 0.78	1	[2] *32.78*	3.04 ± 0.84	1
Svansota [1]	440	2-row *erectum*	32.49	2.54 ± 0.70	2	28.70	1.96 ± 0.54	2	25.14	.02 ± 0.01	2	22.70	.98 ± 0.27	2
Chevalier [1]	230	2-row *nutans*	29.51	.03 ± 0.01	3	26.32	.05 ± 0.01	3	23.97	.84 ± 0.23	3	21.95	2.16 ± 0.60	3
Improved Manchuria [1]	184	6-row common	26.85	4.91 ± 1.35	4	22.27	4.22 ± 1.16	4	18.05	3.77 ± 1.04	4	14.25	3.56 ± 0.98	4
Average	.....	.....	33.04	2.66 ±	.....	29.28	2.18 ±	.....	25.80	1.87 ±	.....	22.92	2.44 ±	.....
WINTER WHEAT		Type and time of maturity												
Minturki [1]	1507	*vulgare*, med	[2] *22.31*	1.57 ± 0.43	1	[2] *19.30*	1.43 ± 0.39	1	[2] *18.68*	1.58 ± 0.44	1	[2] *18.83*	1.71 ± 0.47	1
Minhardi [1]	1505	*vulgare*, med	18.74	.52 ± 0.14	2	16.61	.38 ± 0.11	2	16.10	.25 ± 0.69	2	16.28	.15 ± 0.04	2
Odessa	943	*vulgare*, late	18.51	.81 ± 0.22	3	15.84	1.09 ± 0.30	3	15.67	.87 ± 0.24	3	15.74	.82 ± 0.22	3
Buffums 17	1651	*vulgare*, med	15.82	.95 ± 0.23	4	14.04	1.52 ± 0.36	4	13.11	1.43 ± 0.34	4	12.97	1.56 ± 0.37	4
Average	.....	.....	18.84	.96 ±	.....	16.45	1.36 ±	.....	15.89	1.28 ±	.....	15.55	1.06 ±	.....

[1] From Plant Breeding Section, University Farm. [2] Discard point for crop season.

In the oat varieties, the removal of two and three border rows from either side of each plot involves two changes in rank, but in neither instance does the change involve a change of the variety from one side of the discard point to the other.

In the spring wheat tests, the removal of two border rows from either side of each plot, changes the rank of the spring emmer and moves it above the discard point for that method of test. This position is maintained where three rows are removed from either side of each plot.

In the barley and winter wheat tests, the removal of border rows brought about no changes of rank.

SUMMARY AND DISCUSSION OF RESULTS.

The results show that, in 1921, there was increased yield in the outside and middle border rows for the winter wheat varieties where the alleys were not cropped and for the spring grains separated by alleys cropped to winter wheat. The effect on the inside border rows (the third from the outside of the plots) was nil for the winter wheat and slight for the spring wheat.

Cropping the alleys between the plots of spring grains to winter wheat reduced border effect so that it was not plainly evident at any time before the grain was harvested. This reduction is reflected in the relatively lower yields of the outside border rows of spring wheat, expressed in percent based on the yields from the central rows, as compared with the results secured in 1918 and 1917. For the oat and barley varieties, this reduction in border effect is not apparent from the yields of the outside rows expressed in percentages of the central rows because the fact that there was unavoidable loss of grain in harvesting the lodged central rows with the binder. This resulted in yields lower than they should be from the central rows and consequently higher percentages for the outside rows based on the yields from the central rows.

The three-year average yields of the outside rows of oats, spring wheat and barley expressed in percent based on the yields of the central rows is 199.8 and that of the middle border rows (inside rows in 1917) is 138.0.

Results secured in 1917 with Kubanka wheat (9), under dryer conditions, were 182.4 per cent for the outside and 127.7 percent for the second rows based on the yields of the six central rows. All portions of the plots were harvested by hand. The effect did not extend to the third rows in the plots. The uncropped alleys varied from 16 inches to 38 inches and one was a cultivated roadway several feet in width. There appears to be some correlation between width of alley and amount of border effect but the number of determinations

was too small to give conclusive results. The amount of increase in yield in the border rows in this trial is very similar to the three-year average under Minnesota conditions.

The yields of the outside and inside border rows in the variety plots separated by alleys were in almost every instance considerably higher than the yields from the central rows. Where variety or rate of seeding plots have been planted without the intervention of alleys, border rows have given yields both considerably above and below the yields for the central rows. This point is brought out in work reported from Nebraska (5). Although no statement is made regarding the plan of the plots in the variety and rate of seeding trials, it is assumed that there were no alleys between these plots. Therefore, the plants in contiguous plots came into direct competition and both higher and lower yields resulted in the border rows as compared with the yields from the central rows.

Available data emphasize the necessity of considering border effect seriously in variety and rate of seeding trials, both when no alleys intervene and when the plots are separated by cropped or uncropped alleys.

The results for the varieties separated by alleys in plots without and with border rows removed for a three-year period, show that the removal of the outside border row from either side of each plot reduced yields approximately 10 percent and when two border rows were removed from either side of each plot the yields were reduced approximately 17 percent. When the border effect extended to the third row (inside border row) it was relatively unimportant.

That border effect in plots separated by uncropped alleys does make a different interpretation of results necessary in some instances has been shown (1). In 1921, the third year that work of this kind was carried on, one variety was moved from below to above the discard point for the year by the removal of border rows.

The fact that on each of the three years, one or more varieties or rates of seeding was moved from one side to the other of the discard point for the year by the removal of border rows compels the conclusion that this operation was necessary in order to secure reliable results.

It is possible that under other conditions this operation may not be necessary. Careful experimentation covering a period of years is the only way in which this point can be settled.

The knowledge that border effect is not uniform for all varieties precludes the use of any percentage figures derived in one place to reduce yields secured in another location to a border-effect-free basis.

LITERATURE CITED.

1. ARNY, A. C. and HAYES, H. K. Experiments in field technic in plot tests. *In* Jour. Agric. Res., v. 15:251-262. 1918.
2. ARNY, A. C. Further experiments in field plot technic, *In* Jour. Agric. Res., v. 21:483-499. 1921.
3. FLETCHER, F. Note on a toxic substance excreted by the roots of plants. *In* Mem. Dept. Agric. India, Bot. Ser., v. 2:1-16. 1908.
4. HAYES, H. K. and ARNY, A. C. Experiments in field technic in rod-row tests. *In* Jour. Agric. Res., v. 11:399-419. 1917.
5. KIESSELBACH, T. A. Studies concerning the elimination of experimental error in comparative crop tests. Nebr. Agr. Exp. Sta. Research Bul. 13. 1918.
6. MONTGOMERY, E. G. Competition in cereals. Nebr. Agr. Exp. Sta. Bul. 127. 1912.
7. WIANCKO, A. T., ET AL. Report of Committee on Standardization of Field Experiments. *In* Jour. Amer. Soc. Agron., 10:345-354. 1918.
8. WOOD, T. B. and STRATTON, F. J. M. The interpretation of experimental results. *In* Jour. Agric. Sci., v. 3:417-440. 1910.
9. MARTIN, J. H. Unpublished data secured at Newell, South Dakota, in 1917.

THE EXTENT OF NATURAL CROSS-POLLINATION IN SOYBEANS.[1]

C. M. WOODWORTH.[2]

INTRODUCTION.

The soybean is normally a self-fertilized plant. The flowers are extremely small, so small, in fact, that manipulation during artificial crossing is almost impossible without the aid of a binocular or a hand lens. There are ten stamens closely surrounding the pistil, and at the time when the stigma is receptive, the anthers burst open, covering the stigma with an abundence of pollen grains. As pollination occurs just before the flower opens, the chances of foreign pollen gaining entrance and effecting fertilization are very small.

NATURAL HYBRIDS.

Nevertheless, some natural crossing does occur. Piper and Morse (1)[3] found in bulk seed produced in 1907 certain oddly colored seeds, some of which produced plants whose progeny showed segregation in seed color, pubescence color, and flower color, thus proving the original seeds to be hybrids. They believe, however, that cross-

[1] Papers from the Department of Genetics, Agricultural Experiment Station, Madison, Wisconsin, No. 31. Published with the approval of the Director of the Station. Received for publication, March 15, 1922.

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[3] Reference by number is to "Literature cited," p. 283.

ing in soybeans is far from common, and that "the percentage of hybrids that occur is very small, perhaps not one individual in two hundred."

Woodhouse and Taylor (2) conclude from their observations at Sabour, India, that "natural crosses do not occur on the plains of India to such an extent" as that noted by Piper and Morse in America. They grew seventy-five or more plots, each derived from a single plant selection, and found only one of these to be a hybrid (presumably so-called because it showed segregation in one or more characters, while the other plots did not). In a few other plots rogues were found which may have been the result either of crossing or of chance admixture. These had not yet been tested when the above work was published.

In the work of the Department of Genetics of the Wisconsin Agricultural Experiment Station with soybeans, in 1914, it was observed that the progeny of a single plant was of two types with respect to growth habit. One type was stocky, compact, low and early maturing; the other was stout, more luxuriant in growth, higher yielding and later maturing. These two types occurred in the ratio of three of the late maturing to one of the early maturing type. Also, in the same year, progeny of another single plant showed two different and distinct pod colors, one a very dark brown, the other a light brown. The ratio of plants bearing dark brown pods to those bearing light brown pods was, again, as three to one.[1] Progenies of other single plants have been noted which showed evidence of segregation in flower color, seed color, cotyledon color, etc., and which were proof, therefore, of the hybrid nature of the parent Woodworth, 3).

The foregoing instances of segregation clearly show that natural crossing does occur in the soybean. In view of that fact, it was important in our experimental work to know how often we might reasonably expect natural hybrids to be produced among unbagged plants. An experiment was accordingly planned in 1916 to determine this point in a definite manner.

The writer is indebted to Professor L. J. Cole for helpful suggestions and advice in the conduct of these experiments.

EXPERIMENTAL.

Soybean flowers are either purple or white. Purple is dominant to white, and the two colors form an allelomorphic pair. Plants

[1] Detailed data on the inheritance of these characters will be presented at another time.

known to be homozygous for purple flowers were grown two feet apart in the row, and between every two of these, so that they alternated with them, white flowered plants were interpolated. As the branches of the two types intermingled, abundant opportunity was afforded for crossing between them.

Crossing might occur in any one of four different ways: (1) white flowers might cross with white, or (2) purple with purple on the same or on different plants; or (3) pollen from white flowers might fertilize purple; and lastly, (4) pollen from purple might fertilize white. Only the last named type of cross was made use of in this experiment since it is the only one in which the crossing can be readily determined in the plants of the succeeding generation. Seed from the purple-flowered plants will of course produce plants with purple flowers whether crossing has occurred or not, and hence these have no value as a test. Seed from the white-flowered plants will, if the flowers were self-pollinated, or fertilized by pollen from other white flowers, produce only plants bearing white flowers; but if crossing has occurred with the dominant variety, then such seed should produce some plants bearing purple flowers. The percentage of such hybrid seed, then, may be taken to represent about one-fourth of the total amount of crossing, since this is only one of four ways in which crossing may occur.

In the fall of 1916 many pods were saved from each of seven white-flowered plants from the rows previously mentioned, and these seeds were planted in the spring of 1917. Fifty-three pods from 3 of these plants were kept separate, and the seeds from each pod were planted together so that it could be determined whether, if one seed from a particular pod proved to be a hybrid, the other seeds from that same pod were hybrid also. A total of 91 plants was produced from these 53 pods, and all bore white flowers, thus showing no evidence of crossing. The remaining pods saved from the 3 plants above-mentioned, and all the pods saved from the other 4 plants, were shelled, so that the relationship of the beans to the pods was lost. These seeds produced 114 plants, all white-flowered. Altogether, therefore, 205 plants were grown and not one showed evidence of hybridity.

On the average, soybean pods of the white-flowered variety (S. P. I. 20405) used in this experiment contain 2 seeds. The 205 plants tested, represent, therefore, about 100 pods. If one pod were crossed the percentage of crossing would be 1 percent, if there were only this one way in which crossing could take place; but

since there are four different ways, and one is as likely to occur as any other, the true percentage of crossing would be 4 percent. However, not one pod out of the estimated 100 tested proved to be the result of a cross; hence we may conclude that for the varieties tested in this experiment and for this season the natural crossing was probably less, but at any rate, not greater than 4 percent.

In the second experiment, cotyledon color was substituted for flower color. As shown in another paper (Woodworth, 3) green cotyledon is recessive to yellow. While two factors for yellow (duplicates) were involved in the cross under consideration, the result, for our purpose, was the same as if only one factor were involved. The advantage in using cotyledon color instead of flower color in this experiment is evident in the fact that, like endosperm color in corn, it appears one generation ahead of a mature plant character, and the number of hybrid seeds can be obtained directly without having to test them. In this instance one could be reasonably sure that any yellow-cotyledoned seeds found among the greens borne by plants of the green-cotyledon type were hybrids.

In 1918, two plans of planting were followed. In the first plan (A), the first (outside) row was planted to Variety 8, a yellow-cotyledoned variety (S. P. I. 20406), the second row was planted to both Variety 8 and also Variety 9, a green-cotyledoned variety (S. P. I. 20854), the plants of the two varieties being alternated in the row. (These varieties flower at about the same time, though Variety 8 is a trifle earlier.) The third row was planted to Variety 8 alone, the fourth to the two varieties alternating, and so on. Thus the odd-numbered rows were planted to the yellow-cotyledon variety, while the even numbered rows were planted to both varieties. In the second plan (B), the two varieties alternated in every row. The plants in both plans stood one foot apart in the row, and the rows were one foot apart. Thus, as in the first experiment, abundant opportunity was afforded for natural crossing to occur. Only the green-cotyledoned plants were harvested, and besides the individual plant number they were designated A or B, according as they belonged to the A or the B plan of planting. In harvesting, the pods were picked from each plant, and each pod examined for hybrid seed.

Plants in plan A (43 in number) produced a total of 1,464 pods, of which only one was a hybrid. This pod bore two seeds, one of which had green, and the other yellow cotyledons. Plants in plan B (112 in number) bore a total of 6,016 pods, of which two contained hybrid seed. Both pods were three-seeded, and in one all the seeds

were hybrid, while in the other only one seed was a hybrid. Altogether, 7,480 pods were produced by the 155 plants harvested. Three of these pods contained hybrid seeds, or .04 of 1 percent. This number would be approximately equivalent to one hybrid pod in 2,500. Since this, however, is only one out of four ways in which crossing may occur, the actual proportion would be approximately one hybrid in 625 pods produced, or .16 of 1 percent. This figure is considerably lower than the estimate given by Piper and Morse (*loc. cit.*).

Direct proof of the hybrid nature of these yellow-cotyledon seeds has been presented in another paper (Woodworth, 3).

The percentage of natural hybrids above given is not thought to hold for all varieties, or for all localities, or for all seasons. Much depends on the time of flowering of the contiguously planted varieties, the intervening distance, and the presence or absence of minute insects, such as thrips, which are believed to play a large part in the occurrence of natural cross pollination of soybeans. It is necessary to secure more data on different varieties and in widely separated localities before one can arrive at a proportion which will be generally applicable.

As was indicated by the above data, a flower may be partly cross-pollinated and partly selfed. Indeed, this would appear to be the more general result as only one of the three hybrid pods contained seeds all of which were hybrid. This fact emphasizes the necessity of examining each pod separately.

HYBRIDS BY MUTATION.

Heterozygous plants may also arise as a result of mutation. Take the character flower color for illustration. If in a homozygous purple strain, the factor for purple should be lost or otherwise made ineffective by a mutative change in one gamete and no such change should occur in the other gamete, then the seed resulting from the union of these two germ-cells would produce a plant heterozygous for purple flowers. The progeny of such a plant would show segregation just as if the parent plant were the result of a natural cross. Of course, the number of mutations in soybeans is probably small, but it is reasonable to believe they do occur. It may even be probable that the progenies which segregated in growth habit in one case and pod color in the other (as noted above in our work) came from plants which were the result of mutation, tho the evidence appears to favor natural crossing as the cause. This emphasizes the fact, however, that little dependence can be

placed in the amount of crossing determined by the frequency of occurrence of heterozygous plants in the field.

PRACTICAL SIGNIFICANCE.

The experimental plant breeder must know at all times the source and parentage of the strains with which he works. Few, probably no, crop plants are exclusively self-fertilized, but there is great diversity among them with respect to the frequency with which natural crossing may occur. This relative frequency will determine what care should be taken in making sure of the purity of the breeding material. If, for example, natural crossing occurs so seldom that bagging all plants is rendered unnecessary, then that fact is worth knowing.

It is important that strains made pure by years of selection be kept pure. As soon as crossing occurs, deterioration in yield is a common result. Uniformity of product is also sacrificed, and market standards cannot be met, and the result is discrimination and reduced prices. If the producer knows the chances of crossing between his varieties and those of his neighbor, he can more intelligently determine the distances that should intervene between them to prevent such crossing.

SUMMARY.

1. Natural hybrids are shown to occur in the soybean.

2. In a total of 205 seeds from recessive white-flowered plants, none proved to be hybrid. When cotyledon color was used as an index of hybridity, only three pods in a total of 7480 contained hybrid seed. If all ways in which crossing may occur are taken into account the proportion would be one hybrid pod in 625, or .16 of 1 percent.

3. The percentage of cross-pollination may presumably differ according to the variety, the locality, and the season.

4. Hybrids may also arise by mutation.

5. It is important to the experimental plant breeder and to the farmer to know how much natural crossing may be expected under given conditions.

LITERATURE CITED.

1. Piper, C. V. and Morse, W. J. The soybean; history, varieties, and field studies. U. S. Dept. Agr. Bur. Plant Indus. Bul. 197. 1910.

2. Woodhouse, E. J. and Taylor, C. S. The varieties of soybeans found in Bengal, Bihar, and Orissa and their commercial possibilities. Mem. Dept. Agr. India, v. 5:103–175. 1913.

3. Woodworth, C. M. Inheritance of cotyledon, seed-coat, hilum, and pubescence colors. Genetics, 6:481–553. 1921.

THE EFFECT OF FERTILIZERS ON THE GERMINATION AND BACTERIAL DEVELOPMENT OF INOCULATED SOYBEAN SEED.[1]

T. B. HUTCHESON AND T. K. WOLFE.[2]

It is a common practice in Virginia for farmers to mix together seed and fertilizer and to sow the mixture from the same compartment of the drill. In this procedure, the seed and fertilizer come in intimate contact. The effects of the fertilizer material on the germination and the bacterial development of inoculated seed are of great importance. Questions in regard to these effects have often been asked by many of the people who have used this method of planting seeds.

The investigations reported in the paper were begun for the purpose of studying possible effects of certain fertilizer materials on the germination of inoculated soybean seed and the nodule development on the roots of the plants.

MATERIALS AND METHODS USED.

A sandy loam soil, on which soybeans had never been grown, was selected for this experiment. The soil was placed in flats one foot square and three inches deep. The experiments were conducted in the greenhouse. Soybean seed were inoculated with a pure culture of the soybean organism before planting and they were planted in direct contact with the different fertilizer materials. The rate of planting was two bushels per acre, which allowed fourteen seed to each flat. In addition to those fertilized, two flats were left unfertilized to serve as checks on the fertilizer materials. The fertilizers used and the rates of application are shown in Table 1. In order to find out whether the soil already contained the nitrogen fixing bacteria, one flat was left unfertilized and planted with soybean seed previously treated with a 0.1 percent solution of bichloride of mercury.

Observations were made on the germination of the seed and on the formation of nodules upon the roots of the seedlings. The percentage of germination was determined by counting the number of plants which appeared above ground. The effect of the fertilizer materials on bacterial development was studied by counting the nodules which developed on the roots of the plants after the soil

[1] Contribution from the Agricultural Experiment Station of the Virginia Polytechnic Institute, Blackburg, Va. Received for publication, March 20, 1922.

[2] Agronomist and Associate Agronomist, respectively.

was carefully removed from the roots by washing with water. The counts were made at the end of thirty and forty days. One half of the plants were used for the first count, and the remaining half for the last count.

RESULTS.

The results secured are shown in Table 1.

TABLE 1.— *The effect of fertilizers on the germination and bacterial development of inoculated soybean seed.*

Amount of fertilizers applied per acre.	Germination. Number of plants.	Germination. Percentage.	Number of Nodules Formed. First count.	Number of Nodules Formed. Second count.	Number of Nodules Formed. Average count.
Acid phosphate, 200 lbs	13	93	16	8	12
Acid phosphate, 300 lbs	13	93	6	8	7
Acid phosphate, 400 lbs	12	86	9	5	7
Check	14	100	11	9	10
Muriate of potash, 100 lbs	14	100	10	14	12
Sulphate of potash, 100 lbs	14	100	14	12	13
Nitrate of soda, 100 lbs	14	100	5	7	6
Ammonium sulphate, 100 lbs	14	100	10	6	8
Dried blood, 100 lbs	14	100	8	8	8
Check	14	100	11	11	11
Basic slag, 300 lbs	13	93	11	15	13

The soybean seed treated with bichloride of mercury and planted in the unfertilized soil gave a germination of 93 percent and none of the plants produced showed any nodule development. These results indicate the condition of the soil was favorable to the germination of soybean seed and that the soil did not contain the soybean organism. In view of these results it may be assumed, that if the nodule development on the roots of plants is decreased on certain of the fertilizer plats, the decrease was due to the fertilizer applied.

It may be seen from Table 1 that the fertilizers and the rates of applications used are the ones generally employed in ordinary farm practice. The acid phosphate used contained 16 percent available P_2O_5 and the basis slag contained 18 percent available P_2O_5.

The seed planted in the two check plats germinated 100 percent. If any of the fertilizers used have had an injurious effect on germination, the percentage of germination should be significantly lower than 100 percent. A glance at the table will show that none of fertilizers at the rate applied decreased germination to any appreciable extent. These results are in accord with those previously secured by the authors[1] on a sandy loam soil. However, it was

[1] HUTCHESON, T. B., and WOLFE, T. K. *The effect of fertilizers on the germination of seeds.* Va. Agr. Expt. Sta. Ann. Rept. 1918–1919, 33–37.

found in the previous investigation that fertilizers had a more deleterious effect on the germination of soybean seed on a silt loam than on a sandy loam soil. The injurious effect of fertilizers on germination of soybean seed was much less when the fertilizers were broadcasted and worked in the soil before the seed were planted, than when the fertilizers were distributed in the row and the seed placed in direct contact with the fertilizers.

The average number of nodules developed in the plants of one check was ten, while eleven was found on the plants of the other check. The number of nodules produced on the plants grown under the different fertilizer treatments were not markedly less than those found on the roots of the plants grown in the check flats. These results indicate that at the rate these fertilizers were used no pronounced injurious effect was produced on the bacterial development of inoculated soybean seed.

The results secured on this investigation may have been entirely different had the seed been mixed with the fertilizers and allowed to remain several days before planting. In this experiment the fertilizers were applied in the row and the seed planted and covered with soil immediately. Soil type has also been found by the authors [2] to affect the influence of fertilizers on the germination of seed.

The results indicate that the fertilizers, at the rate used in this experiment, when applied to a sandy loam soil in direct contact with soybean seed, did not have any appreciable detrimental effect on the germination of the seed or on the development of nodules on the roots of the plants.

AGRONOMIC AFFAIRS.

Summer Conference of New England Agronomists

Under the auspices of the New England section of the American Society of Agronomy and in cooperation with the Maine Agricultural Experiment Station and Aroostook County Farm Bureau, some thirty agronomists, pathologists, and others interested in problems of potato production spent three days, August 8–10, 1922, in Aroostook County, Maine, inspecting potato fields and discussing problems of certification and production. The following program was rendered:

Aug. 8th and 9th.— Important features of potato culture in Aroostook County — En route Annual Farm Bureau Inspection Trip. County Agent Edward W. Morton.

[2] Loc. cit.

Aug. 8th, 8:00 P. M.— Fort Fairfield.

What purchasers expect in the way of certified potato seed. Discussion led by Prof. J. S. Owens of Connecticut, County Agent J. H. Putnam of Massachusetts, and R. C. Parker, formerly County Agent on Long Island.

Aug. 9th, 8:00 P. M.— Presque Isle.

Certification of seed stock in Maine. E. L. Newdick, Maine State Department of Agriculture.

Certification in other states —

New York, Dr. M. F. Barrus;
New Hampshire, Dr. O. R. Butler; *
Vermont, Dr. E. Van Alstine.

Potato Diseases and their Control. Director W. J. Morse, Maine Agricultural Experiment Station and Dr. D. Folsom, Presque Isle Substation.

Aug. 10th, 9:00 A. M.—Inspection of experimental work on potato diseases. Drs. D. Folsom and E. S. Schultz, Presque Isle Substation.

Inspection of triangle fertilizer experimental fields. Drs. Oswald Schreiner and B. E. Brown.

Fertilizer and soil type relationship in Aroostook County. Dr. Oswald Schreiner, Bureau Plant Industry, Washington, D. C.

Necessary grades of mixed fertilizer for New England. Director S. B. Haskell, Massachusetts Agricultural Experiment Station.

A. B. BEAUMONT,
Secretary.

* Presented by Director J. C. Kendall.

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ANNUAL MEETING OF THE SOCIETY

The annual meeting of the American Society of Agronomy will be held in Washington, D. C., on Monday and Tuesday, November 20 and 21, 1922. All sessions will be held in the New Ebbett Hotel, 14th and F streets N. W. Programs will be mailed to members by the Secretary a few days in advance of the meeting.

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THE EFFECTS OF SELF-FERTILIZATION IN TIMOTHY.[1]

H. K. HAYES AND H. D. BARKER.[2]

Studies carried on both in the United States and in foreign countries, notably Sweden, have demonstrated the fact that timothy may be improved by the selection and isolation of the more desirable strains. As timothy is normally a cross-fertilized plant, the practical improvement of commercial varieties is somewhat more difficult than with self-fertilized crops. For this reason the greater part of the commercial seed now used in the United States is of the ordinary unselected sort.

Webber, *et al* (4[3]) suggested the use of self-fertilized seed as a means of testing the transmitting ability of clonal lines. The method used to obtain self-fertilized seed as recommended by Webber, was to cover a group of about a dozen heads with a twelve-pound Manila paper bag just before blooming began. The heads were then shaken thoroughly each morning during the blooming period to insure the distribution of pollen over the pistils. Studies carried on at Minnesota have shown that some timothy plants are highly self-sterile while others are highly self-fertile. Since there is little available information regarding this question and as a knowledge of the mode of reproduction of a crop is essential to the breeder, it seemed worth while to present the results obtained.

Frandsen (1) compared the percentage of seed set under the following conditions: self-fertilization, cross-fertilization, and free-

[1] Published with the approval of the Director as paper No. 332, Journal Series of the Minnesota Agricultural Experiment Station, St. Paul, Minn. Received for publication, June 29, 1922.

[2] Head of Section of Plant Breeding, Division of Agronomy and Farm Management and Assistant Pathologist, Division of Plant Pathology and Botany, respectively.

[3] Reference by number is to "Literature cited," p. 293.

flowering. The following data give a comparison of timothy and brome grass as reported by Frandsen:

TABLE 1.—*Percentage of seed obtained by self-fertilization in timothy and brome grass.*

Species.	Percentage of seeds set: Self-fertilizing.	Cross-fertilizing	Free-flowering.
Phleum pratense	0.8– 8.5	52.0	91.3
Bromus arvensis	66.6–80.0	80.4	77.2–89.2

Apparently timothy is highly self-sterile, while brome grass is apparently self-fertile.

THE MINNESOTA STUDIES.

In a preliminary study, heads of approximately fifty individual timothy plants were used. One or more heads were first covered with glassine bags which were about 6 by 2 inches in length and width, respectively. A Manilla-paper bag was then used to protect the glassine bags from heavy winds and rains. Only one or two seeds were obtained from these fifty plants.

A number of individual plants were then selected and 25 bulblets from each propagated in the greenhouse, the various clonal lines being isolated from each other by means of cheese cloth partitions. Three plants from each of several of the lines were also placed in isolated groups in the small grain nursery at some distance from other timothy plants, only those plants of the same clonal line being placed together. The amount of seed set under these various conditions gives a fairly accurate indication of the fruitfulness of the particular clonal line. As all lines produced numerous heads the differences observed and shown in Table 2 seem most reasonably to be attributed to genetic differences in the ability to produce self-fertilized seed.

In general, there is a marked similarity in the percentage of seeds obtained from a clonal line in the greenhouse and in isolated field plots. The first three clonal lines, T30–30–9, T30–30–21, and T31–64–1, produced a fair amount of seed both in the greenhouse and in the field. Line T31–97–11 is rather highly fruitful in all tests; while lines T32–65–14, T32–32–30, and T1–1–26, are apparently highly self-sterile. Seed of the various self-fertilized lines was planted in the greenhouse in the spring of 1922, the plants being carefully spaced about one inch apart. As shown in Table 3, several of these clonal lines produced a percentage of albino seedlings.

TABLE 2.— *Number of seeds obtained from isolated clonal lines in the greenhouse and from the same clonal lines in isolated field plots.*

Clonal line.	Greenhouse test. Number of seeds, 1919–20.	Greenhouse test. Number of seeds, 1920–21.	Isolated field plot. Number of seeds, 1921.
T30–30–9	56	202	208
T30–30–21	54	37	208
T31–64–1	11	73	208
T31–97–11	331	231	495
T32–65–14	6	0	0
T32–32–30	4	0	15
T1–1–26	1	2	0
T31–31–22	2	0	..
T32–98–24	1	25	..
T32–98–27	1	15	..

TABLE 3.— *Albino seedlings obtained from self-fertilized timothy seed.*

Clonal line.	Number of seeds planted.	Number which failed to germinate.	Number of albinos	Source of seed.
T30–30–9	202	12	0	Greenhouse
	208	26	0	Field
T30–30–21	37	1	5	Greenhouse
	208	4	..	Field
T30–63–23	104	6	1	Greenhouse
T31–31–5	104	6	0	Greenhouse
T31–64–1	73	3	1	Greenhouse
	208	18	4	Field
T31–97–11	208	9	11	Greenhouse
	203	12	8	Field
T31–97–18	84	0	0	Greenhouse
T32–32–30	16	2	0	Field
T32–65–29	7	1	0	Greenhouse
T32–98–24	22	4	1	Greenhouse
T32–98–27	21	0	0	Greenhouse
T1–1–26	2	0	0	Greenhouse

Probably all investigators who have practiced self-fertilization in corn have observed chlorophyll-deficient seedlings. The frequency with which they are obtained is of interest in relation to the frequency of the occurrence of albinotic timothy seedlings. Lindstrom (3, 4) has worked out the genetic relations of the four most common types — yellow, white, virescent-yellow, and virescent-white — which appear in self-fertilized lines of corn. Perhaps their frequency has not been generally appreciated by plant breeders although Hutcheson (2) has reported a test of 1872 self-pollinated ears which were grown under greenhouse conditions. Approximately 36 percent of these ears gave seedling lethals in a part of their progeny, while

a little over 28 percent gave chlorophyll deficiencies which were observable in the seedling state.

Recently, the frequency of chlorophyll seedling deficiencies has been observed in several standard varieties of corn at Minnesota, as shown in Table 4.

TABLE 4.—*Seedling chlorophyll-deficient types observed in normally pollinated and first-year selfed strains of standard Minnesota corn varieties.*

Variety.	Type of pollination.	Number of plants.	Number of chlorophyll deficient plants.
Minnesota No. 13	Normal	1,305	9
Rustler	Normal	880	2
Minnesota No. 23	Normal	792	2
Northwestern Dent	Normal	616	3
King Phillip	Normal	792	1
Longfellow	Normal	880	2
		Number of strains.	Number of strains with chlorophyll-deficient seedlings
Minnesota No. 13	1 yr. selfed	29	17
Rustler	1 yr. selfed	6	3
Northwest Dent	1 yr. selfed	4	2

As corn is largely cross-pollinated the percentage of seedling lethals obtained by the use of normally pollinated seed is very small. The thirty-seven first-year selfed lines were from plants which appeared vigorous and of desirable type as observed in the field. Of these thirty-seven strains twenty-two gave seedling lethals.

Although the number of timothy first-year self-fertilized lines which were grown in the greenhouse is very small the results indicate that chlorophyll-deficient types appear as frequently in self-fertilized timothy, as in corn, since five lines out of a total of twelve tested gave some albino seedlings. Witte (6) has reported a timothy plant which when selfed gave progeny which produced degenerate pistils and ovules. Apparently, therefore, self-fertilization in timothy, as in corn, is a logical means of freeing the strain of undesirable recessive characters.

SUMMARY.

Self-fertilized clonal lines of timothy differed widely. This was probably due to genetic causes as there was marked correlation between the percentage of seed set under various conditions.

Five out of eleven first-year self-fertilized strains gave some albino seedlings in their progeny.

LITERATURE CITED.

1. FRANDSEN, H. N. Die Befruchtungsverhältnisse bei Grass und Klee in ihre Beziehung zur Züchtung. Zeitschr. für Pflanzenzucht, 1:1–31. 1917. Abstract by Ubisch in Bot. Centralblatt. 137, p. 211. 1918.

2. HUTCHINSON, C. B. Heritable variations in maize. *In* Jour. Amer. Soc. Agron. 14:73–78. 1922.

3. LINDSTROM, E. W. Chlorophyll inheritance in maize. N. Y. (Cornell) Agr. Exp. Sta. Mem. 13:3–68. 1918.

4. ———— Concerning the inheritance of green and yellow pigments in maize seedlings. *In* Genetics 6:91–110. 1921.

5. WEBBER, H. J., HUNT, T. F., GILMORE, J. W., CLARK, C. F., and FRASER, S. The production of new and improved varieties of timothy. N. Y. (Cornell) Agr. Exp. Sta. Bul. 313. 1912.

6. WITTE, HERNFRID. Über weibliche Sterilität beim Timotheegras (Phleum pratense L.) und ihre Erblichkeit. Svensk Botanisk Tidskrift 13:23–42 2 Abt. 1919. Abstract by Fruwirth in Zeitschr. Ind. Abstamm. u. Vererb. 28:248. 1922.

THE INTERPRETATION OF MECHANICAL ANALYSIS OF SOILS AS AFFECTED BY SOIL COLLOIDS.[1]

R. O. E. DAVIS.[2]

OBJECT OF MECHANICAL ANALYSIS.

The mechanical analysis of the soil is employed to determine quantitively the relative amounts of the different sized mineral particles making up the soil.[3] The relative amount of these various sized grains has an important bearing on the character of the soil and from the results of the analysis the soil is classified as a "sand," "loam," "clay," etc. Closely related to the mechanical composition of the soil are the waterholding capacity, the power of capillary attraction for water, drainage, ease of tillage, and productivity. The limits set for the definition of the group sizes are largely arbitrary, but are those which have been found to be most practical in operation. The limits adopted by the U. S. Bureau of Soils (2) are as follows: fine gravel 2 to 1 mm. in diameter; coarse sand 1 to .5 mm.; medium sand .5 to .25 mm.; fine sand .25 to .1 mm.; very fine sand .1 to .05 mm.; silt .05 to .005 mm.; clay less than .005 in diameter. The soil classification, based on the texture of the soil

[1] Contribution from Bureau of Soils, U. S. Department of Agriculture. Published by courtesy of the American Chemical Society; read at the Birmingham meeting, April 5, 1922. Revised for publication, June 16, 1922.

[2] Scientist in Charge of Soil Physical Investigations.

[3] Reference by number is to "Literature cited," p. 298.

and indicated by means of mechanical analysis, divides the soil into twelve different classes, as follows:

(a) Soils containing less than 20 percent of silt and clay;

(1) "Coarse sand," over 25 percent gravel and coarse sand, and less than 50 percent of any other grade.

(2) "Sand," more than 25 percent fine gravel, coarse and medium sand, and less than 50 percent of fine sand.

(3) "Fine sand," more than 50 percent of fine sand, or less than 25 percent of fine gravel, coarse and medium sand.

(4) "Very fine sand," over 50 percent of very fine sand.

(b) Soils containing 20 to 50 percent of silt and clay;

(5) "Sandy loam," over 25 percent of fine gravel, coarse and medium sand.

(6) "Fine sandy loam," over 50 percent of fine sand, or less than 25 percent of fine gravel, coarse and medium sand.

(7) "Sandy clay," 20 percent of silt.

(c) Soils containing more than 50 percent of silt and clay;

(8) "Loam," less than 20 percent of clay and less than 50 percent of silt.

(9) "Silt loam," less than 20 per cent of clay and more than 50 percent of silt.

(10) "Clay loam," 20 to 30 percent of clay and less than 50 percent of silt.

(11) "Sandy clay loam," 20 to 30 percent of clay and over 50 percent of silt.

(12) "Clay," more than 30 percent of clay material.

The classification of soils in other countries differs somewhat from that adopted by the U. S. Bureau of Soils, mainly because of the adoption by them of different limits for the various groups of material, determined through mechanical analysis.

EFFORTS OF DEFLOCCULATION.

In the various methods of making mechanical analyses the effort is made to bring about deflocculation of fine particles in the soil before analysis is attempted. When collected in the field the sample of soil is generally in a more or less moist condition, but usually comes into the laboratory in an air dry state. In this condition, there have been formed hard lumps which must be broken down in order to determine the grain composition, and the various methods of preparation attempt to bring about not only a breaking down of the lumps but a deflocculation of the fine material of the silt and clay groups. The different methods recommended for deflocculation are: treatment with acid, rubbing with a rubber pestle, and shaking with water or with water and an alkali.

The centrifuge method of analysis was worked out in the U. S. Bureau of Soils and has been in use by its workers in analyzing

thousands of samples of soils. As preliminary to this method the soil is suspended in water with a few drops of ammonia and shaken for seven hours or more in a shaking machine. Experiments by Briggs, Martin and Pearce (3) have shown that this means of deflocculation gives better results than any other, especially in handling a large number of samples, and that while deflocculation was not quite complete after this length of time the continued shaking for a longer period produced only slight changes. It is quite evident that for the proper separation of the grain sizes a complete deflocculation is desirable, as otherwise small aggregates of material may be classed as belonging to a group with size limits considerably above that to which the individual deflocculated material would belong.

COLLOID CONTENT OF SOILS.

It has long been appreciated that soils contain material of a colloidal nature but it was believed that truly colloidal material was of a small amount and rather insignificant, and that after the treatment described as used in the Bureau of Soils, it would be obtained in the clay group in a mechanical analysis. Various investigators have made efforts to separate the colloidal material, itself, in the soil and it has been believed by Schloesing (4) and later investigators, that the amount ranges from 0.5 to 2 percent in what is termed a clay soil, although by the Atterberg (5) and Williams (6) methods of mechanical analysis a large amount of material is secured, which must be largely colloidal. The method usually used for extraction of the colloid is that of shaking with water and separation through subsidence, allowing the larger particles to settle and the colloidal particles to be withdrawn in the supernatant liquid. The workers in the U. S. Bureau of Soils have been investigating this colloidal content for several years and have worked out a method for extracting samples in which large amounts of soil are shaken up with water and the suspension run through a high speed centrifuge which generates a force of about 17,000 gravity, acting on the average particle. The liquid passing through this centrifuge contains a disperse material which is then collected by suction on a Pasteur-Chamberlain filter. By repeated extractions through rubbing and shaking with water, amounting to about forty operations, it has been shown that amounts perhaps as high as 50 percent of colloidal material are contained in some of the clay soils. This colloid, if separated in this way, may be obtained in the disperse system. The particles show under the ultra-microscope the true Brownian movement and the material when dried is of a horny, resinous character and is highly absorptive for water, dyes, and gases.

COLLOIDAL CONTENT OF SEPARATES.

A sample of soil which on mechanical analysis was shown to contain 51.4 percent of silt and 13.1 percent of clay was tested for its colloidal content. These tests showed that little colloid existed in the sand groups, and that the clay group was made up almost entirely of aggregates of colloidal material while the silt contained about 18 percent of colloidal aggregates.

SEPARATION OF COLLOIDS BY ATTRITION.

It has been indicated by absorption tests that the clay group was made up largely of colloid material, but continued shaking with water did not break up the coagulated particles, or in other words, these particles, made up of groups of agglomerated material, formed into aggregates which were not further broken down by simply shaking with water. It was undertaken to separate the clay group by rubbing and subsidence and it was found that by repeated rubbing with a rubber pestle that some colloid was separated on each treatment and that after repeated treatments (18 to 40 times) there remained a small portion of the original fraction that subsided more quickly, that showed under the microscope angular mineral particles. The bulkier portion of the material appeared identical with the ultra-clay, as the colloidal portion has been called. The angular portion did not exhibit the characteristic properties of the colloidal portion.

That the mechanical analysis as carried out does not necessarily give the true relationship of the mineral particle sizes has been shown in another way. A number of samples of deep sea bottoms were submitted to the Bureau of Soils for mechanical analysis by Dr. T. W. Vaughan of the U. S. Geological Survey. These samples appeared, from the separations made, to contain considerable portions of material falling within the sand and silt groups. However, the material indicated by the analysis as belonging to sand or silt groups could be easily crushed with the finger, leaving on a sheet of paper a black streak. These particles were mere agglomerations of very fine material that were not deflocculated by the treatment of shaking with water. Tests indicated that these samples, although they would be classed by mechanical analysis as loams or sandy loams, were 80–90 percent colloidal with sufficient material of shell particles, as shown by the carbonate test, to furnish the remainder.

It has often been pointed out that it is very difficult to make an accurate mechanical analysis and that different analysts frequently disagree in their results. The explanation seems to lie in the fact that the soil aggregates are not broken up to the same extent and

cannot be entirely deflocculated by any means that will not change in part, at least, the relative proportions of the particles.

DESIRABILITY OF EXPRESSING THE COLLOID CONTENT.

The clay part of the soil has long been regarded by soil investigators as the most active part of the soil. Its absorptive action has been believed to be both physical and chemical (7). It has been shown that this most active portion of the soil is very absorptive and that the absorptive part is probably largely the soil colloid and very little the unaltered mineral particles. Work in this Bureau indicates that this colloidal soil material is probably double silicates of iron and alumina. It is plain from the properties exhibited by this material that the soil solution relations, water retention of soil, and moisture movement all depend very largely on the amount and character of the colloid, also that such physical properties as percolation, clodding, tilth, shrinkage of the soil are influenced by the quantity and distribution of the colloid. This colloid material probably is the plastic material in the soil. In testing the cementing properties of the colloid, or ultra-clay, separated from several soils, its strength when dried was determined by some experiments carried out in our laboratory. The crushing strength of briquettes containing the colloid were compared with similar ones using Portland cement. The briquettes were 25 x 25 mm. of cylindrical shape. Made up with the same sand, 10 percent cement gave a crushing strength of 19 kilos, 10 percent of Cecil clay colloid gave a crushing strength of 122 kilos, and with 10 percent of Susquehanna clay colloid, 96 kilos. A similar series with quartz flour gave, cement, 112 kilos; Cecil clay colloid, 304 kilos; Susquehanna clay colloid, 207 kilos.

POSSIBLE MODIFICATION OF ANALYSIS.

From the foregoing considerations and the experimental results obtained it appears that the mechanical analysis as carried out does not furnish us with the true meaning as to the quantitative distribution of the various sized mineral particles in the soil and that it is particularly desirable to determine the colloid content and its distribution. The different groups of mineral particles, and especially the slit and clay groups, are made up in part of colloidal material, and it is possible that a method may be worked out for determining the amount of colloid in the soil and in the silt and clay groups. The process of rubbing a soil sample in water with a rubber pestle and decanting, while possible, is too laborious and tedious to be employed on a large number of samples in a routine way. Work in

progress indicates that a determination of the colloid by the absorption of water vapor may give the desired information. The major portion of the colloidal material is contained in the silt and clay groups, so that by determining the colloid in the soil and in these two groups, information might be obtained that would show the amount and distribution of this colloid, and as a result the correction that should be applied to the mechanical analysis to show the proper amounts of mineral particles in those groups.

LITERATURE CITED.

1. Various methods of mechanical analysis are described in KING, F. H., Physics of agriculture (1907); WILEY, H. W., Principles and practice of agriculturel analysis (1906); MOSIER and GUSTAFSON, Soil physics (1917); U. S. Dept. Agr. Bur. of Soils Bul. 24 (1904) and 84 (1912); ATTERBERG, Intern. Mitt. f. Bodenkunde 1:7 (1911); WILLIAMS, Forsch d. Gebiet d. Agrik-Physik 18:225 (1895).
2. FLETCHER, C. C., and BRYAN, H. Modification of the method of mechanical soil analysis. U. S. Dept. Agr. Bur. Soils Bul. 84 (1912).
3. BRIGGS, L. J., MARTIN, F. O. and PEARCE, J. R. Centrifugal method of mechanical soil analysis. U. S. Dept. Agr. Bur. of Soils Bul. 24 (1904).
4. SCHLOESING, T. Compt. Rend. 78:1276. (1874).
5. ATTERBERG, A. Mechanische bodenanalyse. II Internationale Agrogeologen-konferenz. Stockholm (1910).
6. WILLIAMS, W. R. Mechan. bodenanalyse. Forsch d. Gebiet d. Agrikultur-Physik (Wollny) 18:225–350. (1895.)
7. LIEBIG, J. Natural laws of husbandry. J. Roy. Agric. Soc. 11:313. (1850); Ibid 13:123. (1852).

SCARIFICATION AS IT AFFECTS LONGEVITY OF ALFALFA SEED.[1]

L. F. GRABER.[2]

The value of scarification for the elimination of hard seeds in alfalfa and clovers has met with a wide-spread appreciation. The Ames Hulling and Scarifying machine is being used on a commercial basis in the seed industry. Evidence of its value is abundant and striking. The immediate germination of commercial lots of alfalfa seed containing 25 percent hard seeds has frequently been found to increase from 70 percent to 90 percent or better, following scarification. With sweet clover, which often contains a higher percentage of hard seeds, the results have been even more pronounced, as Table 1 indicates. Furthermore, there appears to

[1] Published by permission of the Director of the Wisconsin Agricultural Experiment Station. Received for publication.

[2] Professor of Agronomy.

be a benefit from scarification that is not entirely made evident by the ordinary six day germination test.

TABLE 1.— *Effect of scarification on the immediate germination of legume seeds containing more than ten percent hard seeds.*

	Percent of germination.			
	Before scarification.		After scarification.	
Kind of seed.	Immediate.	Hard seed.	Immediate.	Hard seed.
Grimm alfalfa....................	70	25	91	Not given
Grimm alfalfa....................	77	23	94	Not given
Hubam clover....................	60	34	92	2
Yellow blossom sweet clover......	28	60	80	5

In an experiment conducted by the Agronomy Department of the Wisconsin Station, alfalfa seeds still remaining hard after having been in the germinators for six days were removed for further test. One hundred of these hard seeds were obtained from scarified samples and one hundred from the same lots of seed which had not been scarified. These seeds were sown separately and at a uniform depth in a greenhouse flat of fertile loam soil. The flat was placed in the open field on April 6, 1919, where it would be exposed to normal spring weather to avoid the "damping off" fungus difficulties of the greenhouse. After a three-week period, the one hundred seeds still remaining hard in the scarified alfalfa produced forty-six alfalfa seedlings (46 percent) compared with twenty-five seedlings (25 percent) for the hard seeds which came from the unscarified alfalfa. While scarification will not necessarily cause a complete elimination of all hard seeds, as indicated by a six day germination test, it is significant that scarified seeds still remaining hard had been scratched sufficiently to result in the production of nearly twice as many seedlings as obtained under similar conditions with hard seeds selected from unscarified samples.

While these results indicate the effectiveness of scarification for the improvement of immediate germination, its influence on the longevity of alfalfa seed appears to be deleterious in character.

An experiment was begun in September, 1921, to test the effect of age on the germination of forty-four samples of unscarified alfalfa seed which had been stored for periods of from two to twelve years in a cool dry basement. The original germination of the lots was known in all cases but one and ranged from 91 to 95 per cent. The fact that all this seed had been used in field tests and produced excellent stands of alfalfa indicates that the germination must have

been very satisfactory, even in the case of the 6 year old samples where the original germination had not been recorded.

TABLE 2.— *Effect of age on the germination of samples of alfalfa seed stored in a cool dry place for two to twelve years.*

No. of samples.	Age in years.	Original germination. *Per cent.*	Present germination. *Per cent.*
3	10 and 12	94.5	47.0
6	9	92.0	54.2
8	8	91.1	63.9
13	7	91.3	69.6
5	6	Not given	65.6
5	4	95.7	78.8
4	2	93.0	87.5

Carefully conducted tests [3] showed a fairly proportionate decrease in germination with age (Table 2), which ranged from 87.5 percent for the 2-year old lots to 47.0 percent for the 10 and 12-year old seed. In conducting these tests, one lot of seed (not included in Table 2) showed a very rapid deterioration in germination from 89 percent in 1919 to 32 percent in 1922. In three years this lot of alfalfa (Sample No. 597) decreased in germination more than thirty other samples stored under the same conditions from 7 to 12 years. This wide discrepancy resulted in an examination of the records concerning lot No. 597, which revealed that the seed had been used by the state alfalfa growers' association for demonstration purposes. It was harvested in Montana in the fall of 1917, but was not scarified until early in the spring of 1919. Fortunately, a sample of this same lot of seed, taken before scarification for a germination test, was located — the original germination being 85 percent with 10 percent hard seeds in addition. This unscarified seed was tested in April, 1922, and gave an immediate germination of 70 percent, a decided contrast with the same seed scarified three years previous, which only germinated 32 percent.

This led to the assembling of all the sample lots of seed which were used by the state alfalfa growers' association, of which scarified and unscarified portions and original germination tests were available. Four additional lots were found answering these requirements, varying in age from two to three years. Two lots, Nos. 729 and 567, three and four years old, respectively, had been scarified; but the unscarified portions of this seed were not located and for this reason, are not included in the tabular data. The samples were

[3] Special credit is due J. T. Omernik, graduate student, who made the final viability tests.

all carefully tested with the rather surprising comparative results indicated in Table 3.

TABLE 3.—*Effect of scarification on the longevity of alfalfa seeds stored in a cool dry place.*

Sample no.	Variety.	Age of seed in yrs.	Seed treatment.[1]	Percent of germination. Original. Immediate.	Original. Hard seeds.	Final. Immediate.	Final. Hard seeds.
597......	Baltic...	4½	None.....	85	10	70	10
597......	Baltic...	[2] 4½	Scarified...	89	7	32	0
654......	Grimm..	3	None.....	66	[3].....	74	4
654......	Grimm..	3	Scarified...	82	[3].....	29	0
655......	Grimm..	3	None.....	62	[3].....	78	4
655......	Grimm..	3	Scarified...	79	[3].....	31	1
847......	Grimm..	3	None.....	70	25	81	10
847......	Grimm..	3	Scarified...	91	[3].....	40	0
1005.....	Grimm..	2	None.....	70	22	69	14
1005.....	Grimm..	2	Scarified...	91	[3].....	68	4
Average immediate germination of unscarified samples..........................				70.6%		74.4%	
Average immediate germination of scarified samples..............................				86.4%		40.0%	

The scarified portions of the five lots of seed deteriorated rapidly in germination from an average of 86.4 percent at the time of scarification to 40.0 percent at the end of two and three years. The unscarified seed, on the other hand, gave an average increase in immediate germination, at the end of the same periods of time, of 3.8 percent. This can be accounted for by the high percentages of hard seeds which the samples originally contained. It appears that hard seeds, which are practically always viable, gradually soften with age, become permeable, and germinate readily. Comparing the original germination of the treated and untreated lots Nos. 654 and 655, it is safe to say, that the unscarified portions each contained at least sixteen percent hard seeds at the time the test was made. At the end of three years only four percent hard seeds remained, even though these lots were not scarified. Likewise, with the remaining lots, there is a prominent reduction in the percentage of hard seeds with age, except in the case of the unscarified Baltic.

Two scarified lots of seed (previously mentioned), Nos. 729 and 567 decreased in germination when three and four years old to 51 percent and 27 percent from their original viability of 94 percent and 95 percent, respectively.

[1] Unless otherwise indicated, the seed was scarified within five months after harvest.

[2] Scarified when one and one-half years old, at which time original germination tests were made.

[3] Percent hard seeds not recorded in original test.

These results are very pronounced, and while the number of samples tested in this experiment are not numerous, the data indicates quite clearly that scarification undoubtedly exposes alfalfa seed to factors which cause a far more rapid decrease in germination than normally obtains with the untreated seed. From a practical standpoint scarification is often essential for improvement of the immedite germination of some legume seeds, but where these seeds are to be stored for more than one year, as sometimes obtains in the seed industry and frequently in experimental work, the wisdom of delaying this treatment until a few months before seeding is quite evident.

DETERMINATION OF THE SWELLING COEFFICIENT OF DRY SOILS WHEN WETTED.[1]

A. E. Vinson and C. N. Catlin.[2]

No method of determining accurately a physical constant for the swelling of dry soil when wetted, comparable to the hygroscopic water content or to the moisture equivalent, was known to the writers when the method described in this paper was worked out. Tempany[3] has described a method of measuring the shrinkage of soils on drying. From the data obtained by his method, he has estimated the amount of colloids present and judged soils as to their adaptability to certain crops. It seemed that the swelling property of soils might be correlated with other soil properties, if it could be determined with reasonable accuracy. Investigations made in our laboratory on a limited number of soil types indicate that the amount of swelling on wetting is a constant for any particular soil which is susceptible of as exact determination by a strictly empirical method as other physical soil constants.

The purpose of this paper is to make available a new method rather than to present any results that have been obtained by its use. Study of a few soil types shows a certain correlation between the swelling constant and the mechanical analysis, the moisture equivalent, and the hygroscopic moisture content, although there seems to be no fixed ratio. This fact gives added value to the new constant. It will probably be of value in investigating the influence of various soil treatments, such as liming and fertilizing, on the physical char-

[1] Contribution from the Department of Agricultural Chemistry, University of Arizona, Tucson, Ariz. Received for publication June 19, 1922.

[2] Professor and Associate Professor, respectively.

[3] Tempany, H. A., shrinkage in soils. Jour. Agric. Sci. 8:312. 1917.

acter of the soil, as well as a means of determining and recording accurately an important physical constant of soil in general.[4] The method may also be of service in investigating the expansion and contraction of road building material which contains silt and clay, and in studying the probable wet and dry volumes of consolidated river sediments. It is now being used in studying the correlation of the rate of percolation through alkaline soils with the swelling coefficient and the effect of chemical treatment on these properties; but the results are not ready for publication.

DETAILS OF THE METHOD

Preparation of sample.—The sample is sifted through a 2 mm sieve as for mechanical analysis, and dried over sulphuric acid. Drying at 100° C. may possibly change the swelling coefficient of certain soils.

Preparation of the soil disk.—Ten grams of the dried soil is placed in a cylindrical steel die having an opening about one inch in diameter, and is compressed under a hydraulic press at 30,000 to 35,000 pounds. It is essential to distribute the soil evenly over the bottom of the die, because the disk will not be of even density if the soil is heaped up in the center or against the side.. The Buchner laboratory press is suitable for the purpose, and the pressure on this press should be held at 250 kilograms per square centimeter, as indicated by the gauge, for ten minutes. The die is then placed on a hollow cylinder or ring having an opening larger than the disk, and the disk forced out on the press. All soils thus far investigated gave firm, water-free disks with the exception of pure sand, which crumbles. Disks of soils that are very high in organic matter, such as muck, tend to split on the edges when released from the die. This is especially apt to be the case after the dies have become chafed. Frequently several trials are necessary to get perfect disks with such soils. Some soils are elastic and expand slightly when pressed from the die, which makes it difficult to press them into place in the expansion cup. All soils begin swelling at once, due to absorption of moisture from the air, consequently, the swelling must be measured soon after the disks are made. Attempts were made to determine the coefficient of swelling in moist air, but no consistent results could be obtained. There was also a tendency for the outside of the disk to split off, or for the disks to split in two.

The disks are calipered at once with a millimeter screw micrometer reading to one one-hundredth millimeter. It is convenient to support

[4] The writers will gladly determine the swelling constant on a few samples of recognized soil types from other states if accompanied by full information.

the micrometer in a vise or with an ordinary burette clamp. A thin cover-glass is placed between the disk and the jaws of the micrometer on each side to give a better face. Soils of fine texture would not need this, but sandy soils tend to rub off. The thickness of the two cover glasses is measured and deducted from the micrometer reading. The disks should be 5.5 to 6.25 mm in thickness.

The dies must be made with care, best out of tool steel, bored and case hardened, then ground true. Soft steel chafes badly and even wears to such an extent that the disks soon are too large to fit nicely into the swelling cup. The plunger must fit very snugly into the die; otherwise soil will work in between the plunger and the side of the die and stick the plunger. When the plunger is forced out, both die and plunger will be scored and practically ruined. This is especially likely to happen when pressures greater than those recommended are used. The die and swelling cups must be made to correspond, the cup being about one-sixty-fourth inch larger than the disk. Convenient dimensions for the die are four inches in height, with bore one inch in diameter. It may be difficult to grind the die exactly one inch in diameter, but a slight variation will make no appreciable difference in the swelling coefficient. The block should be large enough to give a firm bearing, at least three inches in diameter, and the plunger should be three-fourths to one inch longer than the die.

Measuring the swelling. The dry soil disks, immediately after calipering, are dropped into the brass swelling cup and placed in a convenient vessel on the MacDougal auxograph. The apparatus used in our experiments is illustrated in the accompanying plate. Sufficient water is added quickly and the disk allowed to swell without further disturbance. Maximum swelling takes place usually in 30 to 40 minutes, but some soils continue to swell much longer. The maximum magnified swelling is read off from the sheet of millimeter paper carried on the clock drum of the auxograph, then calculated to absolute swelling by the use of a suitable factor, depending on the length of the arm of the auxograph in use. The absolute swelling in mm of the disk in the vertical direction divided by its thickness gives the swelling coefficient.

The swelling cup should be about one inch deep on the inside, so that disks of soil having the greatest coefficient fill it about two-thirds full when maximum swelling is reached. The sides and bottom of the cup are one-eighth inch thick. The bottom is perforated with large holes so that only a substantial support remains; the sides are perforated with a large number of one-sixteenth inch holes especially close together near the bottom of the cup. The bottom of the cup

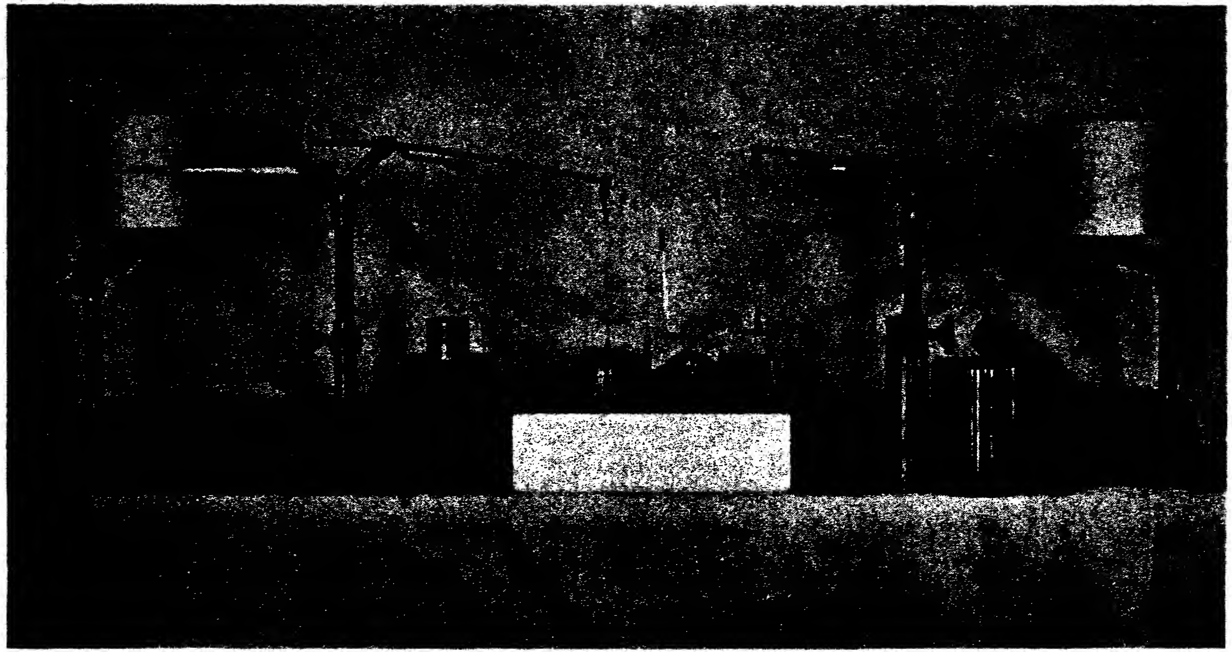

PLATE 1. *Apparatus used for determination of swelling coefficient of soils.*

is covered with a close-fitting piece of circular, flattened brass gauze which supports the soil disk. A second similar brass gauze, which rests on the top of the soil disk, is carried on a fine glass rod attached to the arm of the auxograph. The pieces of flattened brass gauze are prepared by pressing circular disks of brass gauze in the die used for making the soil disks. Glass disks cannot be used, since they do not permit the escape of air bubbles, and, consequently, heave when the water comes in contact with the soil disk. The cup is mounted on three feet about one-quarter inch high, so as to allow ready access of water under the disk.

The water vessel may be made by carefully leveling a glass plate in softened paraffin in the bottom of a crystalizing dish. The bottom of the water vessel must be level as must also the firm support on which it rests.

The adjustment of the brass gauze attached to the auxograph arm requires much care, or satisfactory checks will not be obtained. The water vessel with the swelling cup and soil disk is brought under the auxograph and so adjusted that the gauze disk bears firmly on the soil disk at all points. The disk is pressed firmly but lightly on the soil disk and the pen set at zero on the millimeter paper. A light weight is placed on the arm of the auxograph to prevent the gauze disk from floating before it becomes wet when the water is added. Distilled water is then poured quickly into the water vessel almost to the top of the swelling cup and the weight removed instantly from the arm of the auxograph. Some soil will drop out through the perforations in the cup, but this does not affect the readings. The disk swells at first very rapidly, then slower and slower until the maximum swelling is reached, where it remains indefinitely if not disturbed. The wet, swollen disk will now be found in about the same condition as consolidated wet soil that has not been disturbed for a long time; that is, it corresponds to a fully swollen colloid. Occasional erratic results may be attributed to jarring the apparatus, slipping of the chain links or other parts of the auxograph, failure to adjust properly the upper gauze disk on the soil disk, the water vessel and swelling cup not being level, or failure of air bubbles to escape freely through the gauze disk. Results varying much from the average should be discarded.

The arm of the auxograph as designed by MacDougal gives a minimum magnification of ten. The variation in the swelling coefficient of different soils is much too great to permit their determination on this instrument without varying the thickness of the disk. Since the method is entirely empirical, it would be undesirable to vary the thickness of the disk materially, and our investigations indicated

that consistent results could not be obtained on the same soil by the use of disks of varying thickness. Attempts to dilute strongly swelling soils with sand so as to give the same thickness of disk also proved unsatisfactory. It is therefore best to have an arm on the auxograph twice the usual length so as to reduce the magnification to five in the case of soils whose swelling coefficient would throw the pen below the drum if the 1:10 magnification were used. The ratio between the movement of the gauze disk on the auxograph arm and of the pen may be calculated from the length of the levers, or, better, may be measured directly by means of the millimeter paper for the pen and the cathetometer for the disk.

The lever system of the auxograph is carefully balanced so that almost no pressure bears on the expanding soil disk.

ACCURACY OF THE METHOD

The following table gives a fair idea of the checks which may be obtained on the swelling of consecutive disks from the same dry sample of soil when the method is carried out carefully.

TABLE 1.—*Showing checks on the swelling of consecutive disks and the average swelling constant.*

Kind of soil.	Auxograph reading in millimeters.	Magnification of swelling.	Absolute swelling in mm	Average thickness of dry disk in mm	Swelling constant.
Calcareous gravelly loam	34.5	....	....	....	....
	34.0	....	....	....	....
	33.5	....	....	....	....
	35.5	....	....	....	....
	33.5	....	....	....	....
Average.............	34.2	1:10	3.42	5.7	60
Maricopa gravelly loam	43.0	....	....	....	....
	43.0	....	....	....	....
	43.0	....	....	....	....
	42.5	....	....	....	....
	43.0	....	....	....	....
Average.............	42.9	1:10	4.29	5.75	74.6
Silt and clay sediment from river.	51.0	....	....	....	....
	51.5	....	....	....	....
	51.0	....	....	....	....
Average.............	51.16	1:5	10.233	5.89	174
Muck...............	54.0	....	....	....	....
	54.0	....	....	....	....
	53.5	....	....	....	....
	53.0	....	....	....	....
Average.............	53.62	1:5	10.72	5.91	181

COMPARISON WITH OTHER CONSTANTS

Table 2 shows the correlation between the mechanical analysis, the moisture equivalent as determined with the Briggs-McLean centrifuge, and the swelling coefficient.

TABLE 2— *Comparison of swelling coefficient with other constants.*

Mechanical analysis	Muck	Rillito clay	U. of A. sandy loam	Maricopa gravelly loam	Calcareous gravelly loam
Fine gravel	....	....	.4	2.3	3.6
Coarse sand	1.0	1.2	1.7	9.0	16.1
Medium sand	3.4	7.6	3.5	8.9	16.2
Fine sand	19.7	6.2	21.9	20.4	18.8
Very fine sand	19.6	7.5	45.4	39.7	25.5
Silt	25.7	21.5	11.3	7.6	10.6
Clay	30.3	55.1	15.8	9.7	6.0
Total	99.7	99.1	100.0	87.6	96.8
Loss on ignition	9.71	11.14	12.76	3.93	3.54
Moisture equivalent	33.0	34.8	8.0	9.0	7.2
Swelling coefficient	181.4	173.7	67.5	74.6	60.0

THE RATE OF SWELLING

Different soils show marked differences in the rate of swelling, and chemical treatment modifies this rate enormously. A calcareous, silty clay, deposited from the overflow of the Gila River, after partial neutralization of the calcium carbonate with acetic acid then drying gave nearly the same swelling coefficient as the untreated soil; but the treated soil required two hours to swell the same amount as shown by the untreated soil in five minutes. The study of the rate of swelling cannot be done advantageously with the clocks on the regular MacDougal auxograph, since these are set to give the drum one revolution in one or seven days. A clock giving one revolution of the drum in fifteen or twenty minutes will probably be found most suitable for the study of the rate of swelling. This phase of soil swelling has been little studied.

THE TEACHING OF SOILS.[1]

FIRMAN E. BEAR.[2]

A knowledge of the principles of chemistry, physics, geology and biology is fundamental to the study of soils. In their application they constitute soil science. The student learns in the chemical laboratory

[1] Contribution from the Department of Agricultural Chemistry and Soils, Ohio State University, Columbus, Ohio. Received for publication September 10, 1922.

[2] Professor.

that acids and alkalies neutralize each other. In the application of this principle he finds that the nitric acid produced in the decomposition of organic matter in the soil has its natural neutralizing agent in limestone. Physical science teaches among other things that if a glass tube is placed in a vertical position in a liquid there is usually an elevation but at times a depression of the liquid within the tube. In the application of this principle it is found that water tends to rise in the soil from lower levels to take the place of that lost by evaporation or transpiration from the surface. In the study of geology it is discovered that the original igneous rocks, through the action of weathering agents and of running water, go to form limestones, sandstones and shales. In the field the student learns that the soils resulting from the weathering and disintegration of these three types of rocks differ fundamentally in their natural productive capacity and the explanation soon becomes apparent. Among other things the biological laboratory offers opportunity for the study and classification of microscopic forms of plant life. The application of this in soils discloses the highly important fact that at least three species of micro-organisms are concerned with taking nitrogen from the air to be utilized by the growing crops and that without them the fields would soon be barren of vegetation.

Soil science can be taught by the chemist as a part of the general course in chemistry or as a specialized course following it. The chemist is quite as likely, however, to have his chief interest in some other application of chemistry such as engineering, medicine, pharmacy, metallurgy or animal nutrition as in the soil. In arranging his laboratory exercises and in directing the line of thought of his students the instructor chooses his illustrations usually from the particular application of the science in which his own chief interest lies. Under the stimulating influence of a good teacher the student who may have originally intended to be a farmer finds himself more interested in perhaps medicine or metallurgy and his supplementary reading, study and ultimately his practice may be devoted to that application of the science of chemistry.

The agricultural student is most fortunate, however, when his work in chemistry is under the direction of some professor who came from the farm and whose interest in agriculture has grown with increasing knowledge of the laws of chemistry. With such instruction the student not only finds himself under competent guidance in the study of chemistry as such but also feels an increasing interest in and respect for the science as he sees the numerous points at which previously observed facts on the farm are clearly explained by the application of its principles.

Of necessity all men were not born to be farmers. Many students of chemistry have their chief interest in some other line of endeavor. It is probably best that the instructor in charge of the course in general chemistry in a high school, college or university be rather widely informed as to the applications of chemistry and sympathetic with the variety of needs of his students. It is too much to ask of him that he give to each group of students that more specialized instruction which is possible when they are classified in groups according to their intended profession and the instructor is chosen because of his special interest in that field.

In universities which include colleges of agriculture and in which the enrollment in that college is heavy, it should be possible to provide instruction in chemistry fitted to the needs of the student by choosing the instructor on the basis of his sympathetic interest in the application of the science to agriculture. Such a man need be no less of a chemist but he might well afford to be more of an agriculturist. Such an arrangement does not argue for a department of agricultural chemistry but it does make it essential to have a department of chemistry interested in agriculture. In the absence of such interest the department of agricultural chemistry has had its origin, has continued to exist and appears still to be essential in most state universities. For a similar reason the Smith-Hughes departments have been introduced into the high schools.

But soil science is more than chemical science. The soil is made up of particles of rock and its disintegration products, of living organisms and their remains and contains in its interstices varying amounts of water and air. The productivity of a soil is not determined entirely by its chemical content but also by its physical make-up and the activities of the biological agencies which find their home in it. The limiting soil factor in crop production may be a deficiency or an excess of water, oxygen or carbon dioxide as well as of the elements derived from the soil minerals. The extent to which the requirements of the crop can be satisfied is determined by the ability of the farmer to control the physical and biological factors quite as often as the chemical factors although they are all three intimately related. At any given time the primary cause of failure may not be known. If alfalfa fails to grow it may be because it is not inoculated, because the soil is too wet, because it is deficient in phosphorus or perhaps for the reason that the soil solution is too acid in reaction.

When soil is transferred to the laboratory it undergoes changes which alter its productive capacity. There is of necessity a field science of soils which has to do with the study of the soil as it exists and its classification as determined by the agencies which have had

to do with its formation, location and subsequent continued alteration. Fundamental to the study of this phase of soil science is the understanding of geological and climatological principles coupled with those of chemistry, physics and biology.

The man who presumes to teach the science of soils is, therefore, not a chemist or a biologist, a physicist or a geologist but he must know as much of the sciences represented by these specialists as has any significant bearing on his subject. In the absence of adequate training on his part or of his students in these sciences the teacher of soils struggles between teaching the art and the science of managing the soil. The art of agriculture is probably best taught on the farm. The real opportunity for agricultural teaching lies in the science of agriculture and in the capacity of the instructor to lead the student to see the application of science to his problem.

It is undoubtedly true that there is need that the art of agriculture be understood and that the student be trained in it. To milk a cow or to plow a furrow is not particularly difficult and yet one must know how. It is also true that the boy from the farm knows the art of agriculture largely only as it has been practiced on that particular farm. There is, therefore, the necessity for some one to gather together and present as a whole the various pieces of the agricultural art. That is what is supposed to be accomplished in the trade school where the student learns how to do the things which apply to his particular intended trade. The to-be farmer must learn how to lay a tile, to inoculate the alfalfa, to apply limestone or to calculate when he is getting his money's worth in fertilizer. These can be learned on the farms in almost every community although they may not be always gotten on any one farm.

Perhaps it is the function of the Smith-Hughes teacher in the high school or of the instructor in the agricultural college to teach the art of agriculture or of soil management to the end that the boy who takes the course may return to the farm prepared as he might have been in a trade school or perhaps somewhat more slowly even by continuing on the farm under the more or less competent supervision of his father. Or perhaps it is the privilege of the teacher of agricultural subjects to take advantage of the interest which the boy has in the art of agriculture to pave the way for a greater interest in the sciences which underlie the art.

In the study of soils in secondary schools it is essential to remember that the boy may already have in mind that he will later study in an agricultural college or that being stimulated by the interest aroused in the study of agriculture in the high school he may sub-

sequently so decide. In any event the study of soils leaves less time for a study of history, literature, mathematics, general science, language and other highly desirable subjects. If the student devotes his time at an early age to the study of the art or if the application of science rather than to the science itself, and in so doing neglects the other studies which are designed to enable him to interpret the past and anticipate the future progress of mankind he may be making a grave mistake. Similarly in college or university the student may decide to be a teacher or may become engaged in scientific research and may never return to the farm. No matter in what branch of agricultural work he may ultimately be engaged, he is best prepared for it when the instruction leads in the direction of understanding the basic principles with applications selected by the instructor from good practice in such a way as to insure the continued interest of the student.

Every "how" of soil management has a "why" back of it. Take for example the ordinary operation of plowing. When should a sandy soil be plowed? Why? What kind of a moldboard would be best on the plow to be used on a sandy soil? Why? If plowing a sandy soil with a steep moldboard when the soil is wet will improve its physical properties, there must be some general principle involved which would have some bearing on the plowing of any soil. What governs the working qualities of a soil?

Gradually the efficient instructor pushes the discussion in the direction in which there will be an unanswered why, first in the mind of the student, next in the mind of the instructor and finally in the mind of even the most advanced investigator. The student must somehow come to know that real progress in his education comes not from the knowing of isolated facts, but from a knowledge of principles which may have a great variety of applications in addition to those used as illustrations in the laboratory, field or classroom. The more fundamental these principles and the farther in the direction of the ultimate answers they reach, the more numerous will be their applications in practice to the man who understands them thoroughly.

The student of soils, particularly in the high school, but also in the university, must somehow be inoculated with the germ of dissatisfaction in the knowledge of practical facts alone which leads him on to desire to know what the study of physics, chemistry, geology and biology may have to offer in explanation of these facts. Admittedly, the successful farmer must practice farming and he may succeed financially without ever having seen the inside of a

book on science. He may manage the soil to the end that large yields of crops are produced without his having looked through a microscope or having worked with a chemical balance. If the high school or the college is to do anything more for his son than could be done for him in practicing agriculture on his father's farm, then it must get back of merely useful facts to the principles involved. What and why is the soil?

STUDIES ON THE EFFECT OF NITROGEN APPLIED TO OATS AT DIFFERENT PERIODS OF GROWTH.[1]

W. F. Gericke.[2]

Is the stage of growth of plants, or their age, when nutrients are applied a factor that affects the quantity and quality of product obtained from a given unit application of nutrient? To secure data on this subject was the purpose of series of experiments with a number of agronomic plants (cereals and non-cereals) carried out in pot cultures under greenhouse conditions. Results from experiments with oats where nitrogen was supplied and made available to the plant at different periods of growth is the subject matter of this paper.

It was conceived to be probable, that if the different growth phases, or ages, of the plants when nitrogen is applied plays an important role in determining the magnitude of growth obtained from the treatment, that the differences would be greater if the tests were carried out with a soil that was deficient in nitrogen rather than one not lacking in this constituent. A very satisfactory soil was found in one known locally as Oakley sand. It was not only low in nitrogen, but had proved itself by many tests to be a soil that responded very quickly in increased crop production upon receiving even a moderate amount of either nitrate of soda or ammonium sulfate. The optimum water contents for plant growth in this soil was equal to approximately 18 percent of its dry weight. The containers used for the tests were glazed stone jars of cylindrical shape, of one-gallon capacity. The jars were filled to hold 5.5 kilograms of soil. The soil was seeded with a select strain of Texas Red oats. When the seedlings were about two inches high, they were thinned out to seven plants per jar.

[1] Contribution from the Department of Plant Nutrition, Agricultural Experiment Station, Berkeley, California. Received for publication, May 15, 1922.

[2] Assistant Professor of Soil Chemistry.

All of the essential features pertaining to the technique of the investigation can be briefly stated as follows: The experiment was one in which the same kind of oats was planted at the same time, in the same kind of soil and subjected to the same climatic and cultural conditions. Each culture received the same kind of nutrient and the same amount of nutrient, but the nutrient was applied at different times in the growing period of the plants. That is, the plants were of different ages when they received nitrogen.

Two sets of tests were conducted, one using $NaNO_3$ and the other $(NH_4)_2SO_4$, as the source of nitrogen. All treatments were carried out in triplicate. The amount of nitrogen added per culture was at the rate of 82 pounds per acre on weight basis of 2,000,000 pounds of soil per acre. This was equal to 110 pounds per acre, calculated on basis of area. The application of nitrogen was 250 mg. per culture and was applied in solution at one time.

The data obtained from the investigation are given in tables 1 to 4, inclusive, of this paper:

TABLE 1.— *Effect of nitrogen applied to oats at different periods of growth on time of maturation of the plants.*

(Average of three cultures per set.)

No. of sets.	Date of planting.	Date nitrogen was applied.	Description of plants when nitrogen was applied.	Date of harvest. $NaNO_3$ series.	Date of harvest. $(NH_4)_2SO_4$ series.
1......	11/ 6/19	11/ 6/19	....	5/20/20	5/20/20
2......	11/ 6/19	11/25/19	10–15 cm. high, 3–4 leaves, color of flag normal.	5/20/20	5/20/20
3......	11/ 6/19	12/ 8/19	15–20 cm. high, 4–5 leaves, slightly pale as compared to set No. 1.	5/20/20	5/20/20
4......	11/ 6/19	12/23/19	25–35 cm. high, 5–6 leaves, noticeably paler than set No. 1.	5/28/20	5/20/20
5......	11/ 6/19	1/13/20	30–40 cm. high, 5–6 leaves, pale green as compared to No. 1.	5/28/20	5/28/20
6......	11/ 6/19	2/ 3/20	35–40 cm. high, 6–7 leaves, very pale green as compared to No. 1.	6/ 3/20	6/ 3/20
7......	11/ 6/19	3/2/20	40–60 cm. high, 6–7 leaves, pale green, tips of lower leaves dead.	6/10/20	6/10/20
Check..	11/ 6/19	....	....	6/10/20	6/10/20

Table 1 contains a brief description of the plants when nitrogen was applied and the dates when the plants were harvested.

The first application was not made to any growing plants, but to the soil and the seed. Nineteen days after planting when the visible seedlings were approximately twelve days old, nitrogen as $NaNO_3$ and as $(NH_4)_2SO_4$ was applied respectively to two sets of three cultures each. At this time it was not evident that any of the cultures were retarded in growth because of an insufficient supply of nitrogen. However, with all subsequent treatments, beginning with that made 33 days after planting, all untreated cultures were less vigorous and luxuriant than were those cultures which had already received nitrogen. The vigor and luxuriance of the untreated plants, as compared to those that had received nitrogen, became progressively less as they grew older.

It soon became evident that as a result of the treatments the different cultures in a series were at any given time (beginning six weeks after the experiments were started) in different phases of growth, although all were planted at the same time. The first plants to come to maturity were those of sets 1, 2 and 3 of the $NaNO_3$ treatment, and sets 1, 2, 3 and 4 of the $(NH_4)_2SO_4$, treatment. All subsequent applications of nitrogen to the cultures delayed maturity, when the plants are considered as a whole. But, if only the length of the growing period of the head-bearing stalks of the plants be considered, then the later the nitrogen was applied, the shorter was the growing period of the head-bearing stalks. This is explained by the fact that tillering started in all cultures after nitrogen was applied; and the later the tillers started, the shorter was their period of growth. The plants which matured last were those of the untreated cultures.

It appears from the results thus obtained, that under certain conditions when the rate at which nitrogen becomes available to oats is of such low order as not to permit of fairly good aerial growth of the plants, the life of a plant is thereby prolonged. Perhaps this is due to the slowing up of metabolic processes. This can arise from an insufficiency within the plant at certain times of the proper elements that are needed for the synthesis of plant products. While this condition may hold at times, under other conditions, as, for example, when the supply of nitrogen is deficient and air conditions make for excessive transpiration, the life of cereal plants may be shortened by the inadequate supply of a given nutrient.

Table 2 shows the effect of the treatments on the number of stalks produced and height of which they grew. As seven plants

TABLE 2.— *Effect of nitrogen applied to oats at different periods of growth on number of stalks produced and height of stalks.*

(Average of three cultures per set.)

No. of set.	Days after planting N was applied.	$NaNO_3$ series. No. of stalks.	Direction of maximum deviation from mean.	Height of stalks cm.	$(NH_4)_2SO_4$ series. No. of stalks.	Direction of maximum deviation from mean.	Height of stalks cm.
1.....	......	8.5	+1.5	165	12	± .0	158
2.....	19	11.3	+.7	164	13	±1.0	159
3.....	33	13.3	—1.3	166	15.7	—1.4	153
4.....	48	16.7	—.7	154	19.7	+2.3	153
5.....	69	16.7	—.7	149	20.3	+.7	148
6.....	90	22.0	±2.0	119	23.0	±.0	119
7.....	118	21.7	—1.7	97	22.3	+2.7	104
Check.	......	7.7	—.7	91	7.3	+.7	91

were allowed to grow in each jar, it is apparent that very little tillering occurred on the plants of the untreated cultures. The cultures that received $NaNO_3$ at the time of planting produced a small, but nevertheless, significant increase in number of stalks over those of untreated plants; and the cultures that received nitrogen as $(NH_4)_2SO_4$ produced decidedly more stalks than did the untreated cultures. All subsequent applications of nitrogen applied to different sets of progressingly older cultures up to and including those of set 6, resulted in a marked and apparently progressive increase of tillers. The exception to this continuity of progress is that of set 5 in the $NaNO_3$ series. Apparently the number of stalks in sets 6 and 7 is approximately of the same order of value and the maximum increase produced by varying the time in the growing period of oats when nitrogen was supplied was within that range delimited by these two sets.

The data further show that the application of nitrogen to these oat cultures at different periods of growth of the plants had a marked effect upon the height of the stalks. The tallest plants were produced in sets 1, 2 and 3 of the $NaNO_3$ series. The corresponding sets of the $(NH_4)_2SO_4$ series were shorter. Beginning with set 4 of the $NaNO_3$ series and set 5 of the $(NH_4)_2SO_4$ series, nitrogen applied to progressingly older plants produced correspondingly shorter stalks. The plants with shortest stalks were those of the untreated cultures.

If the height of stalks be multiplied by the number of stalks obtained for the different sets, an expression of response is obtained which is of a different order than that of either of the two factors. The progressive increase in number of stalks per culture produced by the treatment is eventually accompanied by a decrease in the height of stalks. That is, the direction for

the maximum attainment of either one of the two kinds of growth responses due to the same kind of treatment opposed the other. If a curve be plotted for total elongation of the cultures per set due to treatment, it will be found to compare fairly well to that of one plotted for the total dry weight of the cultures of the series.

The data showed that rather extensive tillering, induced relatively late in the growing period of oats, results in plants with short stalks. Two different factors may be conceived to account for the results: (1) the effect due to crowding and competition arising from excessive tillering may decrease height of stalks for number of stalks; or (2) since increasing number of tillers arose from applications of nitrogen made to increasingly older plants, and since the total length of the growing period of oat plants is probably determined by genetic factors, it may be that the later the tillers arise, the less time they have to grow and attain height.

TABLE 3.—*Effect of nitrogen applied to oats at different periods of growth on dry matter production.*

(Average of three cultures per set.)

		$NaNO_3$ series.				$(NH_4)_2SO_4$ series.			
No. of set.	Days after planting N was applied.	Weight of grain gm.	Direction of maximum deviation from mean.	Weight of total dry matter gm.	Direction of maximum deviation from mean.	Weight of grain gm.	Direction of maximum deviation from mean	Weight of total dry matter gm	Direction of maximum deviation from mean.
1.....	......	12.1	+2.7	43.7	+10.3	15.1	—.8	59.2	+3.6
2.....	19	14.3	+.4	64.1	—7.4	18.6	—1.8	66.5	+5.4
3.....	33	13.6	+1.4	75.3	+1.0	18.2	+1.7	67.6	+3.8
4.....	48	20.3	+.6	76.6	+9.4	21.6	—1.6	91.3	—12.0
5.....	69	20.6	+2.9	75.9	+4.5	20.1	—1.5	71.9	+12.3
6.....	90	25.7	—3.7	74.7	—7.7	22.2	+2.3	61.6	+6.4
7.....	118	13.2	+.2	35.9	+.7	15.9	—2.9	38.8	—6.2
Check.	......	2.6	.....	10.1	+1.7	2.6	+1.0	10.1	+1.7

Table 3 shows, first, that the production of grain and straw in the check or untreated cultures was very small as compared to that obtained from the cultures that received either $NaNO_3$ or $(NH_4)_2SO_4$; and second, that there was a decided increase in grain, straw and total dry weight in the cultures that received $NaNO_3$ and $(NH_4)_2SO_4$ at the time of planting. The production of grain, straw and total dry matter, however, was larger in the case of $(NH_4)_2SO_4$ than with that of $NaNO_3$. As the same amount of nitrogen was added in each case, it appears that these differences in yield must be due to differences in the physiological properties of the two salts. Also, there was, for the major portion of the period of treatment, correlated increase in yield

of grain, straw and total dry matter with each treatment applied to progressively older plants. That is, up to a certain age of the plants, the longer after planting before nitrogen was applied, the greater was the yield of straw and grain. The maximum yield, however, did not occur from the same corresponding sets of applications for the different salts. In the case of $NaNO_3$, the maximum yield of grain came from set 6 where nitrogen was applied ninety days after planting. In the case of straw, the maximum yield was obtained from set 3, that is, when nitrogen was applied forty-eight days after planting. As to the high point of total yield, the data are not definite for the $NaNO_3$ series. The yields of sets 3, 4, 5 and 6, are higher than those of the others, and are of approximately equal value. The maximum yield of grain from the $(NH_4)_2SO_4$ series, according to the data, was that of set 6, but in view of the value obtained from set 4, it appears that it would be better to state that the range of maximum values lies between set 4 and set 6. As to straw and total dry matter production, set 4 clearly gave the largest yields for the $(NH_4)_2SO_4$ treatments. Finally a decided decrease in yield of grain, straw and total dry matter from that of the maximum yield, resulted when nitrogen was applied as late as one hundred and eighteen days (set 7) after planting. In the case of $NaNO_3$, the yield of set 7 represents approximately a decrease of one-half of the maximum obtained when nitrogen was applied to cultures twenty-eight days before. The maximum yield of total dry matter for the treatment of $(NH_4)_2SO_4$ came with set 4, and this was followed by decreases in yield of total dry matter (due to a decrease in yield of straw) with each of the progressingly later applications of $(NH_4)_2SO_4$. The yield of grain of set 7 was approximately forty percent less than that of set 6.

TABLE 4.—*Effect of nitrogen applied to oats at different periods of growth on protein content of grain.*

(Average of three cultures per set.)

No. of set.	Days after planting N was applied.	Percent protein (air-dry basis)			
		$NaNO_3$ series	Direction of maximum deviation from mean.	$(NH_4)_2SO_4$ series	Direction of maximum deviation from mean.
1	....	7.5	+.06	6.8	+.15
2	19	8.0	+.30	7.5	+.76
3	33	8.6	—.60	7.3	—.21
4	48	9.6	+.40	9.6	+.55
5	69	10.8	—.92	10.5	—.04
6	90	12.3	+.48	12.1	+.20
7	118	17.1	—1.30	13.9	+.60

Table 4 gives the percent of protein in the grain. It shows that the ages of the oat plants when nitrogen was applied markedly affected the protein content of the grain produced. The lowest percent of protein was obtained from the cultures that received nitrogen at the time of planting and the highest percent was obtained from the plants that received the latest treatment. The intervening treatments showed corresponding differences in percent of protein of the grain. That is, the older the plants were when nitrogen was applied, the higher the percentage of protein in the grain. The percent protein of the grain

TABLE 5.— *Comparison of data of table 4, ($NaNO_3$ series), with that obtained by calculation, using compound interest law of nine percent increase, compounded every fortnight.*

No. of set	Interval between applications of $NaNO_3$ (days)	Percent protein	Calculated interval (days)	Percent protein
1	....	7.5	....	7.5
2	19	8.0	*19	8.0
3	13	8.6	14	8.7
4	15	9.6	14	9.5
			14	10.4
5	21	10.8	....	....
			14	11.3
6	21	12.3	14	12.3
			14	13.3
7	28	17.1	14	14.5

* Includes germination period; 6–7 days required for seedlings to appear above ground, hence obtained value was used.

TABLE 6.— *Comparison of data of table 4 ($(NH_4)_2SO_4$ series) with that obtained by calculation using compound interest law of ten percent increase, compounded every fortnight.*

No. of set.	Interval between applications of $(NH_4)_2SO_4$ (days).	Percent protein.	Calculated interval (days).	Percent protein.
1	....	6.8	....	6.8
2	19	7.5	*19	7.5
3	13	7.3	14	8.3
4	15	9.6	14	9.1
			14	10.0
5	21	10.5	....	....
			14	11.0
6	21	12.1	14	12.1
			14	13.3
7	28	13.9	14	14.6

* Includes germination period; 6–7 days required for seedlings to appear above ground, hence obtained value was used.

of set 7 was 128 percent greater than that of set 1 in the $NaNO_3$ series, and 104 percent greater than that of $(NH_4)_2SO_4$ treatment for the corresponding sets.

The data of Tables 5 and 6 show that the increase in percent protein of the oats from the treatments follows fairly well the compound interest law of nine percent increase in protein content, compounded every fortnight for four months for the $NaNO_3$ series. For the $(NH_4)_2SO_4$ series, it is approximately 10 percent compounded every fourteen days. If, instead of compounding the increases obtained by the treatments every two weeks, it be compounded continuously, it is found that the data lend themselves to be expressed by the law of organic growth.

An inspection of Tables 2, 3 and 4 shows clearly that the variable factor employed in this investigation, namely, the differences in the ages of the oat plants when nitrogen was applied, produced correlated differences of growth responses. It appears, therefore, that the relative physiological status of oat plants expressed by differences in age and grown under the conditions described, is an important factor that affects the quantity and quality of product obtainable from a given unit application of nitrogen. Furthermore, it appears that this factor can be mathematically expressed and evaluated.

Reference has already been made to the differences obtained in results from equal applications of nitrogen, supplied as different salts, to oats. Analogous differences in yield of product from two different salts were also obtained in similar experiments with spring wheat, winter wheat, rye and barley. These marked and consistent differences in the magnitude of response obtained from equal applications of nitrogen, one supplied as $NaNO_3$, the other as $(NH_4)_2SO_4$, indicates that the cause must be due to differences in the physiological properties of the salts. One of these appears to be in the fact that some time is required for $(NH_4)_2SO_4$ to nitrify and become available as nitrate. An application of nitrogen as $(NH_4)_2SO_4$ should, therefore, according to the findings of these experiments, be expected to produce larger yields when applied at the time of planting than an equal amount of nitrogen applied as $NaNO_3$, because it becomes available as nitrate when the plants are of an age when this nutrient can be more efficiently used.

The results of the experiment appear to show that the age of the plants, grown under the condition described, is a very important factor in the measure of response that may be obtained from

a given unit application of nitrogen. Results obtained from similar kinds of experiments with other cereals confirm the above conclusions.

It appears desirable, however, to emphasize the fact that the results obtained from the differential treatments described are unusually large. Had a soil been used that was not so markedly deficient in nitrogen as the one used in these experiments, the results from so few tests would probably not have been so conclusive.

DISAPPEARANCE OF NITRATES FROM SOIL UNDER TIMOTHY.[1]

JAMES A. BIZZELL.[2]

An examination of the literature reveals an increasingly large amount of attention to the study of crops in their relation to the production of nitrates in soils. The bulk of this work seems to be concerned with the use of green manures and cover crops, and the relative rapidity with which plant materials or residues decompose in the soil with the formation of nitrates. Considerably less attention has been given to the production and disappearance of nitrates in the soil during the growth of the crop. Growing crops constantly remove nitrates from the soil and since plants of different species differ so much in their requirements for nitrogen the comparative effects of crops on nitrate production are somewhat difficult to determine. The accumulated data on this subject have now reached a fairly large volume and while the results are not always easy to interpret they contribute valuable information which is highly suggestive.

The difference between certain species of plants in their relation to the nitrate content of soil has been discussed at length in a previous publication of the Cornell Agricultural Experiment Station (1).[3] To summarize briefly—the nitrate content of soil under timothy, corn, potatoes oats, millet and soy beans was different for each crop when on the same soil. During the most active growing period of the corn crop nitrates were frequently higher under the corn than in cultivated soil bearing no crop. Under a mixture of corn and millet, the nitrates at this period

[1] Paper read at the meeting of the New Orleans meeting of the Society. Received for publication October 18, 1922.

[2] Professor of Soil Technology, Cornell University, Ithaca, New York.

[3] Reference by number is to "Literature cited" p. 326.

were higher than under millet alone although the total crop yields were about the same on both plats. Under corn and oats, the nitrate content was higher during the period when the crop was making its greatest draft on soil nitrogen than in later stages of growth in spite of the fact that the nitrates in the uncropped soil were increasing while those in the cropped soil were disappearing. Under these crops and under millet, nitrates failed to increase late in the season when nitrogen absorption had practically ceased although uncropped soil showed a very large increase in nitrates at that time. The authors suggested that the source of the great differences in the nitrates under the crops mentioned might be due to the inherent differences between plants of different species in their stimulating or inhibiting influence on the production of nitrates,— that during their later period of growth the plants exerted a depressing influence on nitrate formation. Timothy always maintained a lower nitrate content of the soil than did any other crop. A mixture of timothy, Kentucky blue grass and redtop gave similar results. These facts indicated a strongly repressive influence of these plants and suggested a possible cause for the injurious effect of grass sod in orchards on soil in which the supply of available nitrogen is deficient. Since the appearance of the publication cited, results have been obtained which show without exception that timothy and the grasses mentioned maintain a comparatively low nitrate content of the soil, in spite of the fact that grass crops require less nitrogen for growth than do any of the other crops studied. Further emphasis is given to this characteristic effect of grasses by results recorded in Memoir 12 of the Cornell Agricultural Experiment Station (2) to the effect that the drainage losses of nitrates from soil under grass have been smaller than from soil under any other crop. These facts have led us to make further inquiry into the relation of timothy to the soil nitrates, some of the results of which are reported in the present paper. Warrington (3) reported that the amount of nitrate nitrogen in the drainage water from the Broadbalk field, Rothamsted, was considerably less than was expected from the manure supplied and the crop reaped. He was of the opinion that the soil had lost nitrogen by denitrification and that the discrepancy was due to this cause. His result was not wholly experimental as it involved certain assumptions for which no direct evidence could be obtained. The results submitted in the present paper are likewise not entirely experimental, but the evi-

dence appears to be much more direct than that reported by Warrington, and since they point rather strikingly to certain modifications of the soil nitrogen it seems desirable to present them for discussion at the present time.

EXPERIMENTAL WORK.

The experiment was designed primarily to ascertain the effect of a nitrate fertilizer on the growth of apple trees in timothy sod. The soil used in this work is classified as Dunkirk clay loam, a rather heavy compact soil containing practically no material which does not pass the 2 mm. sieve. The nitrogen content in the surface foot is approximately 4,000 pounds per acre. Under favorable conditions of cultivation moisture and temperature, nitrification proceeds rather rapidly, but in its natural compact condition it does not seem to offer a very favorable medium. In the spring of 1917, one-year-old MacIntosh apple trees were set on 1/100-acre plots, using twenty trees per plot. All plots received annual applications of 450 pounds of acid phosphate and 240 pounds muriate of potash per acre. The first applications were made in the fall of 1917. Subsequent applications were made in the spring of each of the years 1919, 1920, 1921. Applications of nitrate of soda were made to certain of the plots in the spring of each of the years 1918, 1919, 1920, 1921. One set of four plots received no nitrate, while each of three other sets received respectively 100, 300 and 900 pounds per acre of nitrate of soda. The replicates of any particular treatment were distributed as much as possible to correct for lack of uniformity of the land. Timothy was seeded with rye in the fall of 1917 and the rye was mowed early in the spring of 1918. In the summer of each of the years 1918, 1919 and 1920 the timothy was cut and the hay left on the land. Determinations of nitrates were made each summer on the dates indicated in the accompanying tables. Samples of soil were taken by making nine borings on each plot to a depth of eight inches and a composite sample made from the portions so obtained. Nitrates were determined by the phenoldi-sulfonic acid method as described by Schreiner and Failyer (4). Moisture determinations were also made on these samples and the figures for nitrates calculated to the dry soil basis. The values for nitrates are expressed in terms of nitrogen pounds per acre-eight-inches using 2,500,000 pounds as representing the weight of the acre-eight-inches. The results are given in Tables 1, 2 and 3.

TABLE 1.— *Nitrate nitrogen, pounds per acre, applied and found during 1918.*

Plot numbers.	Nitrate nitrogen applied May 9.	Nitrate nitrogen found Sept. 4.
1001, 1008, 1104, 1112	None	3.39
1002, 1010, 1106, 1114	15.5	3.50
1004, 1012, 1101, 1108	46.5	2.99
1006, 1014, 1102, 1110	139.5	11.36

TABLE 2.— *Nitrate nitrogen, pounds per acre, applied and found during 1919.*

Plot numbers.	Nitrate nitrogen in soil April 21.	Nitrate nitrogen applied April 22.	Nitrate nitrogen found.		
			July 8.	Aug. 15.	Oct. 11.
1001, 1008, 1104, 1112	2.63	None	2.98	6.19	3.37
1002, 1010, 1106, 1114	3.54	15.5	3.09	5.12	3.12
1004, 1012, 1101, 1108	3.79	46.5	3.39	5.20	3.16
1006, 1014, 1102, 1110	3.47	139.5	11.38	14.04	9.98

TABLE 3.— *Nitrate nitrogen, pounds per acre, applied and found during 1920.*

Plot—numbers.	Nitrate nitrogen in soil April 13.	Nitrate nitrogen applied April 26.	Nitrate nitrogen found.				
			May 18.	June 11.	June 29.	July 15.	Oct. 28
1001, 1008, 1104, 1112	3.15	None	2.30	1.99	2.71	2.16	None
1002, 1010, 1106, 1114	4.52	15.5	3.12	1.99	3.39	2.40	Trace
1004, 1012, 1101, 1108	6.30	46.5	5.15	1.64	3.84	6.31	None
1006, 1014, 1102, 1110	4.77	139.5	47.90	25.40	16.98	11.65	5.27

The most striking effect shown by these figures is the rapid disappearance of the applied nitrate. Since the period during which this occurs coincides approximately with the period of most rapid growth of the timothy, it becomes of interest to know whether the assimilation of nitrogen by the crop is responsible for the removal of the nitrate. In order to obtain some evidence on this point, the apple trees were removed from the plots early in the spring of 1921. The fertilizers were applied to the timothy on April 25 after samples of soil were taken for the determination of nitrate nitrogen. On July 12 the timothy was cut, weighed and analyzed and samples of soil again taken for nitrate determination. The results are given in Table 4.

TABLE 4.— *Nitrogen, pounds per acre, applied and found during 1921.*

Plot numbers.	Nitrate nitrogen April 25.			Nitrate nitrogen in soil and in crop July 12.		
	In soil.	Applied.	Total.	In soil.	In crop.	Total.
1008, 1104, 1112	0.50	None	0.50	2.77	17.12	19.89
1010, 1106, 1114	1.24	15.5	16.74	2.37	20.90	23.27
1004, 1012, 1108	.68	46.5	47.18	3.33	34.59	37.92
1006, 1014, 1110	5.42	139.5	144.92	10.11	70.14	80.25

The figures for the disappearance of nitrates are similar to those obtained in previous years. From the results it appears that where no nitrate was applied nitrates were produced to the extent of 19.39 pounds per acre of nitrogen. The application of 15.5 pounds of nitrate nitrogen did not greatly increase the amount removed by the timothy. With the applications of 46.5 and 139.5 pounds nitrate nitrogen, there was an apparent loss of 9.26 and 64.67 pounds respectively. If it is assumed that the two heavier applications of nitrate have not interfered with nitrification, the discrepancy would be 29.15 and 84.56 pounds respectively. In this calculation, no account is taken of the possibility that the roots and stubble would also contain some of the absorbed nitrate. Since the timothy had been growing on this land for the three preceding years, during which time the roots had largely been produced from previously added nitrate, it does not seem likely that more than a very small proportion of the nitrate added on April 25 could have been contained in the roots of July 12. Granting however that the roots produced during the two and one-half months would be responsible for an amount equal to ⅓ the nitrogen contained in the crop we would still have an apparent disappearance, with the largest nitrate application, of 51.18 pounds nitrogen per acre.

NITRATES REMOVED BY LEACHING.

Unfortunately we have no direct means of estimating the loss of nitrates from these plots by leaching. We do have some indirect evidence on this point which seems to preclude the possibility of very much loss in this way. Grass has been grown continuously for nine years on certain lysimeter tanks, using the same type of soil as was used for the plots already described. The drainage from these tanks has been collected by yearly periods and the nitrates determined. The average annual removal of nitrate nitrogen in the drainage water from these tanks has been 1.45 lbs., while the largest removal in any year has been 6.8 lbs. per acre. We would hardly expect therefore to have an appreciable amount lost in this way from the plots, during the two and one-half months during which the timothy was growing. The losses from the lysimeters represent quantities passing through four feet of soil and there is the possibility that the applied nitrate was carried below the eight inch depth sufficient to account for the discrepancy indicated in Table 4. However, experience has shown that on this soil type nitrates do not

move downward with sufficient rapidity to make this explanation plausible. In field experiments it has been found that even where nitrates are produced in large quantities in the surface the lower strata have not been rapidly increased in concentration. An increase in the first foot of nitrate nitrogen from 37 pounds per acre in May to 170 pounds per acre in October was accompanied by an increase in the second foot of from 20 lbs. to 35 lbs. Further, the rainfall of the period April 25 to July 12, 1921, was exceedingly low, being only five inches, while the average during 1896–1916 for a similar period was eight inches.

LOSS OF NITROGEN FROM SOILS UNDER GRASS.

It is not known whether the apparent disappearance of nitrates in this experiment has been accompanied by a loss of nitrogen from the soil during the four years treatment with sodium nitrate. If it could be shown that the nitrogen content of the soil had been decreased at least part of the removal of nitrates could be attributed to denitrification with the evolution of elemental nitrogen. The nitrogen content of this soil before and after the growing of timothy has not been determined because it seemed very questionable whether the comparatively short duration of the experiment and the difficulty of obtaining satisfactory samples would permit of reliable information on this point. In another experiment on the same soil type in the same field, a mixture of Kentucky blue grass, redtop, and timothy has been grown continuously on the land for ten years. In no case has the nitrogen content of the soil decreased during the ten-year period. By sampling the plots in 1910 and again in 1920 it was found that as an average of eight plots the soil has gained in nitrogen to the extent of 250 pounds per acre foot, exclusive of that removed by the grass, which amounted to 347 pounds per acre; whereas an average of eight plots on which no crops were grown for ten years there has been a loss of 624 pounds of nitrogen per acre foot. In all cases where crops were grown in this experiment there was no loss of nitrogen from the soil that could not be accounted for in the crops removed.

DISCUSSION.

From the evidence presented it appears that the addition of sodium nitrate to timothy sod in the early spring is followed by a rapid disappearance of the nitrate from the surface eight inches of soil and that this disappearance is due only in part to the absorption of nitrogen by the growing crop. The evidence

presented indicates that the discrepancy is not due to leaching nor to the removal of nitrogen from the soil by denitrification. It appears likely that the nitrate unaccounted for has been utilized by various organisms of the soil and that the nitrate is therefore transformed to ammonia or some organic combination. The accuracy of the balance sheet presented is, of course, subject to the limitations of the methods employed, particularly those used for determining nitrates and for the sampling of soils for nitrogen determination. However, the discrepancies observed are so greatly in excess of any probable inaccuracy of the methods the results seem to justify the formulation of the hypothesis already stated and a continuation of the study under more rigidly controlled conditions.

LITERATURE CITED.

1. Lyon, T. L. and Bizzell, J. A. Some relations of certain higher plants to the formation of nitrates in soils. Cornell Univ. Agr. Exp. Sta., Mem. 1. 1913.
2. ——— Lysimeter Experiments. Cornell Univ. Agr. Exp. Sta. Mem. 12. 1918.
3. Warington, R. Lost fertility: the production and loss of nitrates in the soil. Trans. Highland and Agr. Soc. Scot. Fifth series, 17: 148–181. 1905.
4. Schreiner, O. and Failyer, G. H. Colorimetic, turbidity and titration methods used in soil investigations. U. S. Dept. Agr. Bur. Soils Bul. 31. W906.

AGRONOMIC AFFAIRS.

NOTES AND NEWS.

E. N. Bressman, formerly assistant in Farm Crops at Iowa State College, is now head of the Farm Crops Department at the New Mexico State College.

C. S. Dorchester, formerly of the Farm Crops Department, Iowa State College, is now an instructor in Farm Crops at the Minnesota College.

R. R. Spafford, assistant agricultural economist, Bureau of Agricultural Economics, Department of Agriculture, has resigned to engage in business with his father at Falls City, Neb.

Plans were recently announced for the Yearbooks of the Department of Agriculture for 1922, 1923, and 1924. With the 1921 Yearbook, these are to complete a 4-year series of articles, each of which is intended to be a complete discussion of the history and economic status of the subject. The 1921 Yearbook contains articles on wheat, corn, cotton, and beef. The 1922 Yearbook will include hogs, dairying, hay, and forage, small grains,

and forestry. The subjects to be discussed in the 1923 Yearbook include fruits, potatoes and truck, sugar, tobacco, poultry and sheep, and goats. In the 1924 Yearbook there will be articles on horses and mules, roads and transportation, land utilization, land tenure, credit and insurance, country life, and education. Each of the articles will include a large number of charts and graphic illustrations.

Asher Hobson of the Bureau of Agricultural Economics, Department of Agriculture, has been named delegate to the International Institute of Agriculture at Rome, succeeding Dr. W. H. Stevenson, who recently returned to Iowa State College.

C. V. Piper, in charge of forage crops investigations in the Department of Agriculture, was given the honorary degree of Doctor of Science by the Kansas State Agricultural College, in June.

Dr. G. R. Lyman, formerly in charge of the Plant Disease Survey of the U. S. Department of Agriculture, has been appointed Dean of the College of Agriculture of the University of West Virginia, at Morgantown, and will assume his new duties on January 1, 1923.

Dr. F. G. Cottrell was appointed, effective September 20, 1922, Director of the Fixed Nitrogen Research Laboratory of the Department of Agriculture, succeeding Dr. R. C. Tolman, who resigned to become Professor of Physical Chemistry in the California Institute of Technology.

Prof. L. A. Fitz, head of the Department of Milling Industry at the Kansas College, has been granted a year's leave of absence, and is now employed in the Research Laboratories of the Fleischmann Co., in New York City. During Professor Fitz's absence Associate Professor P. L. Mann will be acting head of the Department.

M. A. Carleton, formerly of the Office of Cereal Investigations of the United States Department of Agriculture, now in charge of the development of disease-resistant bananas for the United Fruit Co., has transferred from Panama to Honduras, where he will have better facilities for his work.

Prof. C. F. Marbut, of the Bureau of Soils, Dr. R. O. E. Baker, of the Bureau of Agricultural Economics, and Dr. H. L. Shantz, of the Bureau of Plant Industry of the U. S. Department of Agriculture, made a reconnaissance survey of the Southern Great Plains during the months of September and October. They studied the

distribution of the natural vegetation and of soil types, and also devoted attention to the agricultural economics of the region. The survey included portions of southwestern Nebraska, eastern Colorado, northeastern New Mexico, and the western portions of Kansas, Oklahoma and Texas, extending as far south as Corpus Christi, Texas. In all, about 5,000 miles were covered by automobile.

WESTERN CANADIAN SOCIETY OF AGRONOMY

The editor of this JOURNAL has received a copy of the printed Proceedings of the Second Annual Meeting of the Western Canadian Society of Agronomy, which was held at Winnepeg on December 27–29, 1921. It contains information with reference to the organization and membership of the Society and the following papers:

Address of President — T. J. Harrison.
Growing Grain in Rows — Manley Champlin.
Practical Crop Rotations for the Prairie Farmers — M. J. Tinline.
A Course to Train Specialists in Agronomy — D. W. Robertson.
Laboratory and Field Germination Tests — W. H. Wright.
Wheat-stem Rust from the Standpoint of Plant Breeding — H. K. Hayes and E. C. Stakman.
Discussion of Hayes and Stakman's Paper, " Wheat-stem Rust from the Standpoint of Plant Breeding "— J. B. Harrington.
Alfalfa Hybridization — W. Southworth.
A Comparison of Some Physical Properties of Immaturely Frosted and Non-Frosted Seeds of Wheat and Oats — Jas. R. Fryer.
Peat Land Farming — F. J. Alway.
Soil Colloids — C. B. Clevenger.
The Potato Scab Problem — G. B. Sanford.
Extension Methods that Get Results — S. T. Newton.

Copies of this report and the Proceedings of the First Annual Meeting of the Society are for safe at fifty cents each by the Secretary, Professor Roy Hansen, University of Saskatchewan, Saskatoon, Sask., Canada. A single copy of each of these Proceedings will be sent free, on request, to the library of each of the Agricultural Colleges in the United States.

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INCREASING THE EFFICIENCY OF AGRONOMIC RESEARCH.[1]

L. E. CALL.[2]

The field of agronomy is still a new one in America. Carleton[3] in his presidential address before the first session of this society in 1908 said, "In this country the segregation of agronomic work from general agriculture began with the new century. Before the year 1900 the word *agronomy* was rarely heard or written." The field of activity of the early agronomist was scarcely less restricted than that occupied by the earlier men in general agriculture. He had far too many duties and too many lines of activity to attempt the necessary specialization that would enable him to pursue any carefully planned line of research. A decade ago the agronomy department in most educational institutions was charged with the teaching and the investigational work in agricultural engineering and farm management, as well as in soils and crops, and its small staff attempted to do the extension work in these fields as well. It was not uncommon in our smaller institutions to find the same man engaged in all of these lines of activilty. In fact, fifteen years ago in some of the smaller departments the same man taught courses in general crops, soils, and farm machinery, and often did a limited amount of teaching in farm management and meteorology. In addition, some extension work, as well as experimental work, was attempted. Undoubtedly the greatest improvement in the efficiency of agronomic work in the past has come through gradual elimination of the diverse lines of activity of the agronomist. Today in most institutions the work of the department of agronomy is devoted

[1] Presidential address, presented at the annual meeting of the American Society of Agronomy, at Washington, D. C., November 20, 1922. Contribution No. 143 from the Department of Agronomy, Kansas Experiment Station.

[2] Professor of Agronomy, Kansas State Agricultural College, Manhattan, Kan.

[3] CARLETON, M. A. Development and proper status of agronomy. *In* Jour. Amer. Soc. Agron. 1:17–23. 1908.

exclusively to soils and crops, and in those departments which have the largest personnel, the men are devoting their entire time to teaching, research, or extension in one or the other of these fields. In fact, it is fully recognized that even greater specialization than this is not only desirable but absolutely necessary for the most efficient work. The entire field of either crops or soils is far too large for anyone engaged in research. The breeding of any one crop plant such as cotton, wheat, or corn will furnish a sufficiently large field for any investigator who is well trained in genetics. As the field of activity in crops and soils has been narrowed, the work in each field has improved. This has been the one outstanding contribution of the past twenty years toward greater efficiency in agronomic work.

INTERRUPTION CAUSED BY THE WAR.

The first lesson in efficiency, the need of specialization, had scarcely been learned and our institutions attained a state of development that would permit a reasonable degree of specialization when, due to the world war, all progress was interrupted The service of every available man was required for the conflict. Agronomists frequently proved to be the logical men to serve on committees to devise plans whereby the maximum production of food stuffs could be secured. All their time and thought were devoted to this work. Progress in the technical field of agronomy came to a standstill.

The reconstruction days following the war proved no more satisfactory. They brought problems that were even more distracting than those of the war itself. Prewar appropriations were no longer adequate to support teaching and research. The industries, because of the higher salaries they could pay, were taking the younger men of the profession. It was impossible to replace them. Students were not interested in graduate study. This was not surprising when at the completion of an undergraduate course they could enter a line of industry that would pay a larger salary than that commanded by some of the best trained men in the profession. Those days, however, are slowly but surely passing. Conditions are gradually adjusting themselves. Appropriations are more nearly adequate for the work. More students are interested in graduate study, and there is promise of a more abundant supply of well trained young men in agronomy in the future. However, the world war and reconstruction have occupied a period of time nearly one-half the length of the life of this society. When, therefore, we consider the progress that has been made in agronomic work during this time regardless of the many distractions, it should serve as a stimulus to us to push

forward with renewed energy now that the outlook is brighter for uninterrupted work.

LAYING PLANS FOR THE FUTURE.

Is this not a logical time to consider the defects and shortcomings of our work and to lay plans for more effective and efficient work in the future? The past, as I have endeavored to show, has taught the need of greater specialization. This lesson has been learned. There is some evidence that in certain cases specialization may have been carried too far, especially in the administration of agronomic work, but the principle of specialization has been firmly established.

If agronomic work is to reach the highest point of efficiency in the future, if we are going to improve upon the splendid service of the past, there are several fundamental considerations that must be recognized: (1) The importance of thorough basic training for research must be not only encouraged but insisted upon. (2) There must be a clear understanding of the importance of the research problems that present themselves and an effort must be made to confine our activities and energies to problems of greatest value. (3) There must be in those engaged in research such a love for the work as will enable them to push forward in the face of obstacles which may seem insurmountable. (4) There must be developed a spirit of consecration that will lead not only to a greater degree of cooperation among workers who are attacking the same problem but a closer cooperation among different state institutions, between state institutions and the federal government, between agronomists and workers in other allied sciences, and between agronomists and the general public as represented by industrial concerns and the farmer.

EXPERIENCE AND EDUCATION.

The proper training for the agronomist should start in early boyhood. This period preferably should be spent on the farm. A thorough knowledge of practical farm affairs and an understanding sympathy of the problems of farm life, best learned in the early boyhood days, are an essential foundation on which to build for technical work in agronomy. President Jardine,[4] in discussing this subject before this society in 1917, said: "A practical point of view is largely the result of boyhood training and an endowment of common sense. We who are now directing the training of future agronomists should make it our first article of faith to advise a boy to go into teaching or research in agronomy only when he has

[4] JARDINE, W. M. The agronomist of the future. *In* Jour. Amer. Soc. Agron. 9:385–390. 1917.

shown ample evidence of his thoroughgoing practicality." While a practical knowledge of agriculture is a necessary foundation for the best type of training in agronomy, it is only the first course in the foundation. Upon this must be placed a *general* four year college course in agriculture, followed by a thorough specialized training in those sciences related to the particular field of agronomy in which future work is to be done. It would be impossible to overemphasize the importance of thorough training in the fundamental sciences for the person who plans to engage in research in this field. This is absolutely necessary as the first step toward more efficient work. The war and the unsettled period following it interrupted the study of many who were doing graduate work and upset the plans of many others who were arranging for graduate study. This is a loss that will never be entirely repaired, and as a result, the efficiency of our work has suffered. It is encouraging, however, to observe an increasing interest in graduate study among the younger men in agronomy, as well as among students who have just completed their undergraduate work. It gives promise of a higher standard of work in the near future.

There is a danger that often accompanies thorough training in a specialized field. This is the failure to maintain a correct conception of the relative importance of other lines of work. The worker becomes so impressed with the importance of his own line of activity that the importance of the work of others is underestimated. This develops in time into a professional selfishness that warps the vision, stunts mental growth, and greatly reduces the efficiency of the worker. The danger of developing the so called " single track mind " can be avoided by taking time to investigate and to become interested in the work of others. The time spent for this purpose not only will broaden our vision and help us maintain a correct understanding of the importance of our own work but may give us new ideas that will open up new lines of attack on our own problems. We have represented in the American Society of Agronomy as it is now constituted a sufficient number of lines of research activity to enable those of us who attend the meetings to maintain a fairly broad vision of closely related fields of work. This helps us maintain a breadth of vision that we all need. The man who is devoting his time to field crop genetics is benefited by the discussion of some phase of soil biological work, and in the same way the man engaged in research in soil biology profits by the discussion of the problems of the plant breeder. We may derive even greater benefit in this connection by attending meetings of other societies of pure and applied science. Every

possible opportunity should be used for this purpose. This would eliminate much of the danger of too great specialization, provided through such gatherings as these, and in other ways, a broad vision is secured and a sympathy maintained for other lines of work.

RESEARCH AND OTHER DEMANDS.

In the past the efficiency of agronomic research has been retarded not only by inadequate training and by a constant pressure from the general public for special services, but by poor organization and a failure to grasp the importance of the various problems and to attack those only of the greatest economic importance. While the lack of training on the part of those engaged in agronomic research is being rapidly overcome and while the demand for public service is less urgent than during the war, there nevertheless is a constant demand upon most of us in federal and state institutions for such service We constitute a part of public institutions whose only justification for existence is to serve the people, from whom we obtain our support. Good service leads to an ever increasing demand for additional help. Some of our colleges are developing as service institutions to the point where public demand is so strong that a majority of the time of the entire force of the institution is utilized in this way. It should be remembered that the best service is not necessarily performed when only the call of the hour is answered. Frequently the man in the laboratory working on fundamental problems proves in the end the better public servant. Both types of service must be performed and the most efficient institution is the one which retains the proper balance between these two lines of work. It is often possible to combine basic research with the solution of some practical problems of timely interest. The farmer may be interested in the best crop variety to grow. It is the agronomist's duty to give him this information. While this information is being obtained it may also be possible, if the work is properly planned, to study some of the factors that influence the productivity of the crop under investigation. Thus research of a fundamental nature may often be combined with the more routine types of work that we all must pursue.

Are we wasting time on work that is poorly organized? Are we attacking the problems that are of the greatest importance? Are we marking time because of being engaged in lines of research that we are unable to pursue properly with the resources at our command? If so, are there not problems of the greatest importance that might be attacked with the resources at hand with reasonable assurance of bringing the work to a successful conclusion? Is

there not also a possibility that research methods are being used that are expensive, that consume time excessively, that might be replaced by simpler and less expensive methods? Greater efficiency in research work in agronomy can be brought about by better adaptation of research methods to the problems under investigation, by a more careful organization of the work, and by a thorough study of the problems under investigation; eliminating those upon which progress is not being made and placing greater exertion and energy on those that remain which are of greatest value.

ESPRIT DE CORPS.

There has never been the esprit de corps in agronomy that exists in some of the older branches of science. Until we develop such love for our profession that we are willing to make sacrifices in salary and mere official rank in order to stick to agronomic research, we cannot hope that proper progress will be made by the profession. The American Society of Agronomy in the short period of its existence has had a total of fourteen presidents. Of this number only four remain today in purely agronomic work. Two have become college presidents, four are experiment station or extension directors, two have retired from active service, and two are engaged in commercial fields of work. Perhaps the loss of these men from the field of agronomic research would not have been so serious, because most of them while agronomists were already engaged chiefly in administrative work, had it not been for the fact that when they resigned, their places for the most part were taken by men engaged in research who had won recognition because of their achievements in this field. As long as it remains the practice to take the best research men in agronomy for administrative work it will be impossible to make research work as efficient as it should be. It is regretable that in many institutions it is impossible financially to reward efficiency in research as liberally as efficiency in administration and extension. The United States Department of Agriculture is to be congratulated that Congress has made possible a salary scale for a few men engaged in research higher even than that of the bureau chiefs themselves. These positions should be filled as rapidly as suitable men can be obtained to fill them. They will be filled at the maximum salary available for the position if the administrative officers of the department are willing to lay aside personal feeling in the interest of the development of research. It is recognition of this kind that will hold our best men in research. It is recognition of this kind that will develop an esprit de corps within the ranks of agronomy. May we not hope that the action of Con-

gress in recognizing the value of research marks the beginning of a new day for the men engaged in investigational work?

COOPERATION.

Although thorough training, well developed plans, and love for the work are essential for efficient research in agronomy, they are perhaps less important than a spirit of cooperation in the workers. We have passed the pioneer days in agronomic research when it was possible for an individual working alone to make rapid progress. The problems before us are complicated, they require for solution the best judgment of a number who are specialists in different lines of work and who can view the problems from different angles. The most hopeful sign of increasing efficiency in agronomic work is the growing spirit of cooperation among those working together in agronomy and between agronomists and those engaged in other fields of science.

Cooperation Among Agronomists.

In several sections of the United States where climatic and soil conditions are similar we have agronomists working on problems that are similar, if not identical. While some duplication of work is usually desirable, is there not wasted effort in much of the duplication that exists in agronomic work to day?

We are able to learn something of each other's work in meetings of this kind and in the sectional meetings of the society. We also learn much from published papers and occasional visits to other institutions, but this does not afford the type of cooperation that we should have or that we must have if the work is to be most effective. It should be possible for those engaged in the same line of research in adjoining states of similar character to meet together in smaller groups at least once a year to discuss their work and to advise with each other as to the best way of attacking their problems. Work that is being contemplated should be presented at such meetings and an endeavor made to secure the necessary cooperation on the problem without the danger of unnecessary duplication. The amount of money required to travel to meetings of this character would be insignificant as compared with money which could be saved. The results accomplished by such meetings cannot be measured, however, in money. The most important result is the stimulation to the worker that would come from such gatherings. The soil fertility schools that have been held by the Soil Improvement Committee of the National Fertilizer Association and the conference on lime held in September at the University of Tennessee are steps in this direction. Such conferences are having a tremendously

stimulating influence on the work in these fields. What we should have are more conferences of this character, but before this is possible, our administrative officers must recognize the value of such meetings and arrange for the traveling expenses of the delegates. This, I believe, will come when we who are engaged in the work demonstrate our belief in the value of such meetings by attending some of them at personal expense.

Cooperation Between Agronomists and Other Scientists.

The agronomist must have a thorough training in closely related sciences, not with the expectation of becoming a specialist in these fields of study — for that would be impossible — but for the purpose of recognizing, in any problem that he may undertake, the relation of the various sciences to it. When he recognizes that some other science may contribute to its solution, he should be broad-minded enough to invite cooperation. For example, if the plant pathologist and the agronomist work independently of each other, progress will be slow in developing disease resistant strains of crop plants. Likewise, the agronomist and the entomologist working in cooperation will make much more rapid progress in devising methods of insect control than by working alone. In the same way the agronomist must cooperate with the geologist, the physicist, the bacteriologist, and the chemist in the solution of difficult soil problems. It is in this way that the problems of the future will be solved. The agronomist cannot hope to be a plant pathologist, a plant physiologist, an entomologist, or an ecologist, a physicist, a chemist, or a bacteriologist. He can, however, have the helpful cooperation of these other scientists in many of our well organized institutions if he has the character and the vision to invite their cooperation and to avoid anxiety about who is to get credit for the work. One of our greatest needs today is a group of workers who are willing to forget self for the sake of service.

Cooperation Between the States and the Federal Government.

There has been a splendid spirit of cooperation in the past between the Bureau of Soils and the Bureau of Plant Industry of the United States Department of Agriculture and the Departments of Agronomy of most of the land grant institutions. This has led to extensive and highly satisfactory cooperative work that has been of the greatest help to the land grant institutions, and I believe satisfactory as well to the United States Department of Agriculture. Most agronomic problems are not bounded by state lines. Many of them are regional or even nation-wide in their application. The broader viewpoint which the United States Department of Agriculture must

necessarily take is of the greatest value to the local worker, while on the other hand, the close personal touch which only the man on the job can have has no doubt been of similar value to workers in the Federal Department. How long would it have taken us working alone in state institutions without the cooperation of the Office of Cereal Investigations of the Bureau of Plant Industry to learn that there are regional strains of black stem rust (*Puccinia graminis tritici*)? How long would it take to determine the winter hardiness of a new strain of wheat if it were not for the winter hardiness nurseries of the United States Department of Agriculture conducted in cooperation with the states extending north and south across the country? What progress would the individual states have made in classifying the soils of this country if it had not been for the cooperation of the Bureau of Soils with the various states in soil survey work? These are but a few of many examples that might be cited of the value of the cooperation that has existed in the past between the states and the federal department in agronomic work. Greater efficiency in agronomic work in the future will come through closer cooperation between these agencies than has existed in the past. This will take place if we all endeavor to *give* as much as possible rather than to *get* as much as possible from our cooperative work.

Cooperation Between the Agronomist and the Public.

Of necessity is the agronomist in close contact with the farm and the public. In common with other agricultural workers he is more or less of a middle-man between the man of so called pure science and the man on the farm. It is to the agronomist that the farmer should naturally come with a crop or soil problem. If the agronomist is practical enough and scientific enough to apply the principles of science to the problems of the farm, he will secure the confidence of the farmers and bring about a cooperative relation that will be mutually beneficial. The farmer will obtain the service that he desires, while the agronomist will at all times be informed as to the problems of the farm that require attention.

There is developing rapidly a more friendly relation between the agronomist and agricultural industrial concerns. The industrial concerns are learning that the agronomist is not altogether a theorist, and the agronomist is learning that many industrial concerns dealing with the farmer are endeavoring to render a real service to agriculture. This has led to most friendly cooperative relations with a number of agricultural industries, as, for example, the National Fertilizer Association through its Soil Improvement Committee, the

National Lime Association, and more recently firms interested in the sale of sulfur for agricultural purposes. When we consider the possibilities in this field we are impressed with the small beginning that has been made and the number of lines of industry with which we, as agronomists, should be cooperating.

SUMMARY.

If agronomy in the future is to make the rapid progress that has been made in the past, if it is to retain its present standing in the rapidly developing field of agriculture, if it is to accept its opportunity to render to society the service that the future will afford, a greater effort must be exerted among agronomists to secure the proper, fundamental training for their work. There must be developed an esprit de corps that has not existed in the past. Greater efficiency in research must be secured by closer cooperation and a more generous attitude: first, among agronomists in different state institutions; second, between agronomists in state and in federal work; third, between agronomists and other scientists; fourth, between agronomists and those engaged in industrial enterprises; and, fifth, between agronomists and the general public. These are the conditions necessary for effective work. Is there any reason to doubt that they will be fully accepted? I think not, for there has never been a time when the need for thorough training was more fully appreciated, when workers in agronomy were more earnest, when the desire for cooperation was more sincere, or when the opportunities for service were greater. Nothing must prevent the agronomists of the future from accepting these opportunities.

REDUCTION OF NITRATES CAUSED BY SEED AS A POSSIBLE FACTOR IN THE ECONOMY OF NITROGEN IN CROP PRODUCTION.[1]

JEHIEL DAVIDSON[2]

INTRODUCTION.

As early as 1868, Schönbein (1)[3] reported the fact that water extracts, prepared from seeds of higher plants, possess the faculty of reducing nitrates to nitrites and other more advanced products of reduction. He thought that the dissolved organic materials present

[1] Contribution from the Laboratory of Crop Chemistry, Bureau of Chemistry, U. S. Dept. of Agriculture. Presented at the 12th annual meeting of the American Society of Agronomy, Chicago, Ill., Nov. 10, 1919. Received for publication October 2, 1922.

[2] Soil Chemist.

[3] Reference by number is to "Literature cited," p. 354.

in the extracts had certain catalytic properties similar to those of platinum black and that the reduction was a phenomenon connected with the chemical activation of oxygen as in the case of ozone. In the light of the later theory of enzymes, Schönbein's explanations might be interpreted to mean that the reduction of nitrates by seed extracts was caused by reducing enzymes.

It is now generally accepted, however, that the denitrification attributed directly to the seed by Schönbein is caused by reducing microorganisms which use the materials contained in the seed as food. For instance, toluene, which inhibits bacterial activity but does not affect enzymic action, completely prevents the formation of nitrites by seed in a nitrate solution. Seed which was heated at a temperature of 100° C. for about 24 hours, for the purpose of destroying its vitality, did not lose its ability to reduce nitrates, as will be shown in this paper. The prolonged heating at 100° C. would seem to be sufficient to destroy all the enzymes in the seed. The organisms concerned in the reduction of nitrates indirectly caused by seed, whether found only where grain is grown and stored or not, seem to be of common occurrence. Seed belonging to different varieties, obtained from different harvests and different localities, gave results showing the same denitrifying tendencies.

The object of the work here reported was to obtain quantitative measurements which would give an idea of the possible extent of the reduction of nitrates caused by seed. It was thought that such data would indicate the limits of speculation as to what might happen under actual field conditions.

EXPERIMENTAL WORK.

It was not considered necessary to conduct the experiments under controlled conditions of culture and temperature. The nature of the organisms involved was beyond the scope of this work, which was intended to demonstrate collective results under natural fluctuating conditions. The mixed unidentified causal organisms either were associated with the seed or occurred in laboratory air. The temperature in the laboratory where the experiments were conducted varied with the fluctuations in temperature outside, especially with the changes in the day and night temperature, and with seasonal fluctuation as the work covered a period of several years. This accounts for certain quantitative variations which will be observed in the tables. The figures in these tables should be considered as representing relative rather than absolute values, inasmuch as they were obtained under certain imposed conditions. The tendencies which they reveal, however, are clearly defined.

Influence of Basic Radicles on the Reduction of Nitrates Induced by Seed.

Of the nitrates selected to test the influence of the basic radicles on the process of reduction some are common in soils either naturally or as fertilizers, as the nitrates of sodium, potassium, calcium, magnesium, and ammonium, and some are found only rarely, or in minute quantities, as the nitrates of manganese, barium, cobalt, and copper. The solution of sodium nitrate used had a concentration of 1000 parts per million. The other nitrates were used in normal proportions, so that the concentration of the nitrate radicle was the same in all the solutions.

Two grams of wheat seed was placed in 250 cc. beakers containing 200 cc. of the solution to be tested. The beakers were covered with watch glasses and allowed to stand in the laboratory. At certain intervals aliquots (usually 5 cc.) of the solutions were pipetted off for nitrite determinations which were made colorimetrically, using the modified Griess reagent and a Schreiner colorimeter. The results are reported in parts per million of NO_2. The same procedure was followed in all experiments. The rate of reduction is judged by the accumulation of nitrites in the solutions from day to day and by their gradual disappearance. The ultimate test, however, is the disappearance of the nitrites which in the great majority of cases coincides with the total disappearance of the nitrates.

The first experiment was begun November 18 and concluded December 13. The results are given in Table I.

The process of reduction was sluggish as compared with that of some of the later experiments. A certain intermittence in the accumulation of nitrites indicates that the reduction of the nitrates to nitrites and to the further stages was going on simultaneously. The sluggishness of reduction may have been due to the season of the year. The time when this experiment was conducted corresponds to the period of the year when, according to Moore (2) the reduction of nitrates to nitrites by sunlight is the lowest. While the reduction of nitrates in these experiments is certainly microbiological, and while the nitrite accumulations induced directly by sunlight generally fluctuate between fractions of one part per million and, therefore, could not appreciably affect the quantitative determinations reported here, sunshine intensity may be an important factor affecting the activities of the organisms involved in the reduction of nitrates.

The disappearance of the nitrites occurred earlier in the calcium and magnesium nitrate solutions than in the others. This, however, may have been accidental. The behavior of manganese, which is

TABLE 1.—*Influence of basic radicles on the reduction of nitrates induced by seed.*

(Parts per million of NO_2)

Nitrates.	After 1 day.	After 3 days.	After 4 days.	After 5 days.	After 7 days.	After 8 days.	After 10 days.	After 11 days.	After 12 days.	After 14 days.	After 15 days.	After 17 days.	After 18 days.	After 19 days.	After 20 days.	After 22 days.	After 25 days.
Sodium nitrate....	.5	12	25	16	63	48	160	120	80	60	120	30	Trace	Trace	....	....	....
Sodium nitrate....	.4	20	40	50	54	80	160	120	50	1	1	Trace	Trace	Trace	....	....	....
Potassium nitrate..	.4	12	35	30	72	80	180	140	120	100	120	60	12	None	None	....	....
Potassium nitrate..	.5	7	20	16	45	32	100	60	....	30	30	30	30	8	None	....	....
Calcium nitrate...	.2	14	30	20	72	48	120	120	80	40	Trace	Trace	None	....	....	....	....
Calcium nitrate...	.3	8	20	25	90	80	160	120	100	.4	Trace	Trace	None	....	....	....	....
Magnesium nitrate.	.3	20	40	35	144	80	160	5	Trace	Trace	None	....	None	....	....	....	....
Magnesium nitrate.	.4	17	40	35	90	80	160	100	80	80	Trace	Trace	None	....	....	....	....
Ammonium nitrate.	.7	22	50	25	72	60	160	....	120	120	100	80	24	None	Trace	....	....
Ammonium nitrate.	2.4	14	40	50	126	60	140	120	80	120	120	80	80	24	40	Trace	Trace
Manganese nitrate.	.3	4	14	20	63	60	120	100	50	100	100	60	50	24	32	Trace	Trace
Manganese nitrate.	.3	1.2	3	5	22	24	100	80	50	100	80	80	80	40	50	24	Trace
Barium nitrate....	.1	8	24	40	108	50	140	120	60	120	50	40	None	....	....	....	....
Barium nitrate....	.1	12	45	30	63	100	140	100	100	1	.6	Trace	None	....	....	....	....
Cobalt nitrate.....	Trace	Trace	Trace	Trace	Trace	Trace	Trace	....	....	....	....	....	....	....	....	....	....
Cobalt nitrate.....	Trace	Trace	Trace	Trace	Trace	Trace	Trace	....	....	....	....	....	....	....	....	....	....
Copper nitrate....	None	None	None	None	None	None	....	....	....	....	....	....	....	....	....	....	....
Copper nitrate....	None	None	None	None	None	None	....	....	....	....	....	....	....	....	....	....	....

known to be toxic to higher plants in relatively high concentrations (3) is of interest. While in the concentration used in this experiment, which is to be consdered as high, manganese would seem to have retarded slightly the accumulation of nitrite in the beginning and its disappearance at the end, it nevertheless left the process of reduction essentially unchanged. Cobalt and copper, in the concentrations used in this experiment, entirely prevented reduction.

The results show that the basic radicles of the common nitrates do not affect essentially the process of nitrate-reduction induced by seed. In the subsequent experiments sodium nitrate, the most common nitrate in fertilizers, was used.

Influence of the Quantity of Seed on the Reduction of Nitrates.

Definite weights of wheat seed were placed in 250 cc. beakers, and 200 cc. of a 1000 p.p.m. sodium nitrate solution was measured into each beaker. The beakers were covered with watch glasses and allowed to stand in the laboratory as in the previous case.

This experiment was begun January 23 and concluded February 12. The results are given in Table 2.

The influence of the larger quantities of seed was to hasten the process of reduction, especially, in the more advanced stages which are marked by the disappearance of the nitrites. The maximum nitrite concentration of 600 parts per million was obtained with one gram of seed. It is possible that the rapid disappearance of nitrites began at a lower concentration in the case of the larger quantities of seed. It is also possible, however, that the maximum readings in the case of the larger quantities of seed indicate the first steps in the further reduction of the nitrites. The highest concentrations might have occurred between the date of the apparent maximum and that of the first reading which registered the more advanced reductions as indicated by the decrease in nitrite occurrence. It should be noted that in the case of the highest quantity of seed the total accumulation of nitrites disappeared in a period of time not exceeding two days.

Influence of the Concentration of the Solution on the Reduction of Nitrates Induced by Seed.

Two grams of wheat seed was weighed into each beaker and 200 cc. of each solution was measured into the beakers. The concentration of the solutions ranged from 100 to 10000 parts per million. The experiment was begun March 28 and terminated April 20. At that date the nitrites had not disappeared in the highest concentrations. The results are given in Table 3.

TABLE 2.—*Influence of the quantity of seed on the reduction of nitrates.*

(Parts per million of NO_2.)

Quantity of seed, gms.	After 1 day.	After 2 days.	After 3 days.	After 4 days.	After 6 days.	After 8 days.	After 9 days.	After 10 days.	After 11 days.	After 13 days.	After 14 days.	After 15 days.	After 16 days.	After 17 days.	After 20 days.
1	.....	3.2	13.0	20.0	47.5	93.7	250	400	450	600	550	520	450	320	Trace
1	.....	3.2	10.0	17.5	42.5	81.2	225	320	400	550	450	440	280	None	None
2	.....	8.5	37.5	45.0	106.2	400.0	360	.....	450	143	None	None	.....	.....	.....
2	.....	7.0	37.5	55.0	110.5	320.0	400	.....	312	None	None	.....	.....	.....	.....
5	5.0	37.5	137.5	200.0	237.5	440.0	16.5	.....	None	None	.....	.....	.....	.....	.....
5	4.5	50.0	150.0	275.0	300.0	440.0	None	.....	None	.....	.....	.....	.....	.....	.....
10	10.0	50.0	200.0	275.0	520.0	140.0	None	.....	None	.....	.....	.....	.....	.....	.....
10	10.0	57.5	175.0	275.0	480.0	200.0	None	.....	None	.....	.....	.....	.....	.....	.....
20	15.0	60.0	187.5	312.0	400.0	None	None	.....	None	.....	.....	.....	.....	.....	.....
20	13.0	80.0	225.0	375.0	440.0	None	None	.....	None	.....	.....	.....	.....	.....	.....

TABLE 3.—*Influence of the concentration of the solution on the reduction of nitrates induced by seed.*

(Parts per million of NO_3.)

Concentration $NaNO_3$, p.p.m.	After 2 days.	After 3 days.	After 5 days.	After 7 days.	After 8 days.	After 10 days.	After 12 days.	After 14 days.	After 16 days.	After 17 days.	After 19 days.	After 23 days.
10,000	30	70	100	160	280	112	175	480	560	440	560	560
10,000	35	70	80	140	320	110	200	520	640	440	560	640
5,000	25	70	100	140	400	100	440	520	640	720	900	800
5,000	60	90	120	320	560	175	440	550	720	720	480	80
2,000	30	80	120	400	640	150	18	16	64	None	10.0	None
2,000	30	70	120	320	400	140	Trace	......	......	......	......	......
1,000	30	70	120	100	12.0	90	None	......	......	......	......	......
1,000	50	80	137	5.0	6.0	90	None	......	......	......	......	......
500	25	80	110	1.5	2.5	7.0	None	......	......	......	......	......
500	30	80	120	1.5	2.5	50	None	......	......	......	......	......
200	12.5	60	5.0	2.0	2.5	3.0	None	......	......	......	......	......
200	25	80	3.0	2.0	2.5	3.0	None	......	......	......	......	......
100	25	40	2.5	2.5	2.0	4.0	None	......	......	......	......	......
100	30	40	2.0	2.5	2.0	4.0	None	......	......	......	......	......

Beginning with the concentration of 2000 parts per million, the experiment ran its normal course, except for a certain fluctuation in the accumulation of nitrites. Attention is directed to the large accumulation of nitrites obtained in the higher concentrations of sodium nitrate.

The lowest concentration of 100 parts per million of sodium nitrate used in this experiment is frequently found in soils under natural conditions. The reduction in this concentration followed the same general tendency. Higher concentrations of 1000 parts per million were used in the subsequent experiments for the purpose of better demonstration.

Influence of Surface Sterilization of the Seed on the Reduction of Nitrates.

The experiment was conducted in 250 cc. beakers with 200 cc. of solution having a concentration of 1000 parts per million. Two sets of beakers, one with sterilized seed and one with untreated seed, were used. The seed was sterilized by soaking it in a solution of mercuric chloride (1 : 1000) for 20 minutes. The experiment was begun February 22 and terminated April 4. The results are given in Table 4.

The surface sterilization of the seed retarded the beginning of the process of reduction for about four days. The organisms which were at work in the sterilized set of beakers were either those reinoculated from the air of the laboratory or those of the original flora associated with the seed which survived because of imperfect sterilization. The retardation was probably caused either by the length of time required for inoculation in the case of the first alternative or by that required for the residual organisms to multiply in the case of the second alternative. The disappearance of the nitrites was not as rapid in the case of the sterilized seed as in the case of the untreated seed, probably because of the change produced by the sterilization of the seed in the composition of the causal flora.

Influence of the Depth of the Liquid on the Reduction of Nitrates Induced by Seed.

All the experiments so far reported were conducted in 250 cc. beakers, using 200 cc. of solution. Under these conditions the depth of the liquid was about 6.5 cm. It has been assumed that the process of reduction in these experiments was anaerobic in character, as in the case with biological reduction in general. It seemed desirable, therefore, to determine whether the depth of the liquid had any distinct effect on the process, especially in view of the fact that the depth of standing water over agricultural fields seldom reaches 6.5 cm.

TABLE 4.—*Influence of surface sterilization of the seed on the reduction of nitrates.*

(Parts per million of NO_2.)

Quantity of seed, gms.	Treatment.	After 1 day.	After 2 days.	After 4 days.	After 6 days.	After 7 days.	After 8 days.	After 9 days.	After 12 days.	After 15 days.	After 19 days.	After 23 days.	After 25 days.	After 26 days.	After 30 days.	After 33 days.	After 37 days.	After 40 days.	After 41 days.
10.......	Sterilized	None	Trace	0.3	12.5	62.5	120	160	240	140	120	80	40	40.6	31.2	32.0	4.5	5.0	Trace
10.......	Sterilized	Trace	Trace	0.3	10.0	68.7	180	225	400	240	160	240	100	112.5	90.0	90.0	100	5.0	Trace
5.......	Sterilized	Trace	Trace	0.2	37.5	75.0	200	360	280	326	Trace	8	Trace	None	.....	.....	.....	.....	.....
5.......	Sterilized	Trace	.03	0.4	62.5	75.0	260	225	250	225	120	175	Trace	None	.....	.....	.....	.....	.....
2.......	Sterilized	None	None	0.3	64.0	75.0	220	250	140	6	Trace	Trace	Trace	22.5	None	None	.....	.....	.....
2.......	Sterilized	0.3	0.4	10.0	125	87.5	250	250	300	100	Trace	Trace	Trace	22.5	None	None	.....	.....	.....
10.......	Not sterilized	25	50	150	250	12.0	None	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10.......	Not sterilized	37.5	75	150	.....	0.1	None	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5.......	Not sterilized	25.0	62.5	137.5	275	37.5	None	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5.......	Not sterilized	25.0	81.2	150	160	1.2	None	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2.......	Not sterilized	15.0	45.0	100	260	240	350	360	None	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2.......	Not sterilized	22.5	60.0	110	300	300	32.5	200	Trace	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Two grams of wheat seed and 200 cc. of a 1000 p.p.m. sodium nitrate solution were used in each case. Vessels of different diameters were used in order to obtain the different depths of liquid. The experiment was begun March 28 and concluded April 9. The results are given in Table 5.

TABLE 5.—*Influence of the depth of the liquid on the reduction of nitrates induced by seed.*

(Parts per million of NO_3.)

Depth of liquid, cm.	After 2 days.	After 3 days.	After 5 days.	After 7 days.	After 8 days.	After 10 days.	After 12 days.
1.5	25	70	80	156	180	125	None
1.5	12	60	90	140	160	160	None
6.5	30	70	120	100	12	90	None
6.5	50	80	137	5	6	90	None
22.0	50	90	180	2.5	3	50	None
22.0	40	90	140	125	40	125	None

The depth of liquid did not seem to have any important effect on the process of reduction.

INFLUENCE OF TEMPERATURE ON THE REDUCTION OF NITRATES INDUCED BY SEED.

The previous experiments reported were carried out at the temperature of the laboratory, about 75–80° in the day time. The temperature of the soil at the time wheat is planted, late in the fall or early in the spring, is much lower. If the reduction of nitrates induced by seed under laboratory conditions is also induced under field conditions, such a reduction might be expected in the late fall or early spring. The planted seed requires some time to germinate, after which, in the case of winter grain, comes a period of inactive growth. Excess of precipitation at these periods is also more likely to create anaerobic conditions in the soil, especially in localities of poor drainage, than at any other time. It seemed desirable, therefore, to determine how the process of reduction would be affected by a temperature approximating the temperature of the soil in late fall or early spring. With this point in view, two beakers containing two grams of wheat seed and 200 cc. of a 1000 p.p.m. sodium nitrate solution were placed in the ice box with a temperature of about 50° F. In Table 6 the results obtained from these beakers are compared with those obtained from two identical beakers kept at laboratory temperature. The temperatures of late fall and early spring, as indicated by this experiment, would not in themselves essentially interfere with the reduction of nitrate induced by seed. It would seem that the only effect of the lower temperature was to retard the process of reduction which otherwise followed its normal course.

TABLE 6.—*Influence of temperature on the reduction of nitrates induced by seed.*
(Parts per million of NO_2.)

Temperature of	After 2 days.	After 3 days.	After 5 days.	After 7 days.	After 8 days.	After 10 days.	After 12 days.	After 14 days.	After 16 days.	After 17 days.	After 19 days.	After 22 days.
Room.....	30	70	120	100	12	90	None	....	....	....	....	....
Room.....	50	80	137	5	6	90	None	....	....	....	....	....
Ice box....	2.5	50	100	90	120	80	120	225	320	200	120	Trace
Ice box....	2.0	40	80	80	120	70	120	320	400	240	48	Trace

TABLE 7.—*Influence of destroying the vitality of the seed on the reduction of nitrates as compared to that induced by growing seedlings.*
(Parts per million of NO_2.)

Material.	After 1 day.*a*	After 3 days.*b*	After 4* days.*a*	After 5 days.*b*	After 6* days.*a*	After 8 days.*c*	After 11 days.*c*	After 16 days.*d*	After 17 days.*a*	After 20* days.*c*	After 22 days.*d*
Sterile seed	3.5	20	12	40	12	40	40	11	15	14	10
Sterile seed	8.0	24	16	40	8.0	32	20	8	12	9	10
Growing seedlings	Trace	4	2.5	8	3.2	20	16	1.5	1.2	1.0	1.6
Growing seedlings	Trace	9	3.6	12	6.4	24	28	3.2	2.0	1.6	.....

* Solution not changed. (*a*) One day period. (*b*) Two days period. (*c*) Three days period. (*d*) Five days period.

INFLUENCE OF DESTROYING THE VITALITY OF THE SEED ON THE REDUCTION OF NITRATES AS COMPARED WITH THAT INDUCED BY GROWING SEEDLINGS.

The cause of the reduction of nitrates in the case of growing seedlings had been considered to be different from that obtaining in the case of ungerminated seed. It was thought to be a phenomenon directly connected with the metabolic processes of the growing seedlings.(4) It has been shown by the writer,(5) however, that microörganisms are responsible for the reduction of nitrates in the case of growing seedlings, as well as in the case of ungerminated seed.

As in the case of ungerminated seed, the contribution of the seedlings to the process of reduction is the supply of food materials contained in the mother seeds which is utilized by the reducing organisms. The growing seedlings and the reducing organisms are consequently drawing upon the same source of food. This would suggest the possibility of a competition for food between the growing seedling and the reducing organisms. The growth of the seedlings, therefore, would be expected to interfere with the process of reduction were it not for the possibility that the competition for food which they offer is offset by the increased solubility of the storage products contained in the mother seeds as a result of the processes of growth. It was the object of this experiment to determine whether the growth of seedlings actually has any inhibitive effect on the reduction of nitrates under laboratory conditions.

In the previous experiments the seeds were prevented from germinating by being kept submerged under a deep layer of water, usually 6.5 cm. The results obtained under these conditions could hardly

be compared with the results obtained from growing seedlings, in which case it would be necessary to keep the mother seeds just on the surface of the experimental solutions. The only way to prevent seed from germinating when kept on the surface of the experimental solution was to destroy its vitality. This result was accomplished by subjecting the seed to prolonged dry heating at a temperature of about 100° C.

The heated and unheated wheat seed in quantities of 5 grams was spread out on floating aluminum disks in agate-ware dishes, each containing 1500 cc. of a 1000 p.p.m. solution of sodium nitrate.

The experiment was begun January 17. The first nitrite determinations were made January 18. Germination was seemingly complete on January 20 when the ungerminated seeds in the dishes of the unheated series were removed. The maximum number of seeds which failed to germinate in one dish was 35. Enough seedlings were removed from the second dish of the same series to make a total of 35 with the number of removed ungerminated seeds. Thirty-five seeds were removed from each of the two dishes of the heated series. The quantity of seed was thus essentially the same for every dish. The solutions were usually changed after every determination, in order to prevent any too extensive changes in the concentration of the solution as a result of the growth of the seedlings. The figures in Table 7, therefore, represent not the continuous accumulations of nitrites, as in the previous tables, but accumulations during periods between the dates of two determinations.

The results (Table 7) show that the sterile seed produced more nitrites than did the growing seedlings in every case save one. This exception may be safely disregarded in view of the general character of the experiments previously noted. The heated seed produced larger quantities of nitrites even in the first 24 hours and before the germination of the unheated seeds seemingly could have gained much headway. The decided drop in the production of nitrites induced by the growing seedlings, beginning February 2, occurred about the time that the hulls of the mother seeds were practically emptied of their storage products.

There was a possibility that the greater production of nitrites in the case of the heated seed was due to the effect of heating on the food materials contained in the seed. When compared under the usual conditions in beakers, however, the heated seed failed to produce more nitrites than the untreated seed. It would seem, therefore, that the depressed reduction observed in this experiment was due to the growth of the seedlings, as was expected on the basis of theoretical considerations.

The tendency revealed by this experiment, should it prove to hold true under field conditions, might have some bearing on our agricultural practices. A high sterility in the seed used for planting might not only cause waste of planting material, but also, under certain conditions, a greater reduction of the nitrates present in the soil.

Influence of Soil on the Reduction of Nitrates Induced by Sterile Seed and Growing Seedlings.

The soil used was a silt loam from the Arlington farm. It was mixed with about 30 percent of sand in order to facilitate leaching. One hundred and fifty gram portions of this mixed soil were weighed into wine glasses with perforated bottoms. The bottom perforations were fitted with cork stoppers. Wheat seed was germinated on aluminum disks, the devitalized seed being kept under the same conditions. After the seed had germinated, the seedlings and sterile seeds were transferred to the glasses with the soil, 12 to each glass. All were planted at approximately the same depth. A 1000 p.p.m. solution of sodium nitrate was added to the glasses until it began to drain through the perforations in the bottoms. The perforations were then stoppered with the corks. A small quantity of solution was allowed to stand on the surface of the soil. The glasses were then placed on small glass rings in beakers. In each case the nitrites represent accumulations of approximately 24 hours. When determinations were to be made the corks were removed, the free solution allowed to drain, and their several successive portions of distilled water or fresh sodium nitrate solution passed through the soil in the glasses. The nitrites were then determined in the total leachings. Naturally sterile seed, picked out from the aluminum disks on which seed was allowed to germinate, was used, in addition to that made sterile by heating. The eight glasses of the experiment were treated alike in every case and the results are fairly comparable. The seed and seedlings were transferred to the soil January 18 and the leachings were collected periodically until February 21. The results are given in Table 8.

The high figures of the first readings may be attributed to the available food material originally present in the soil. The check glasses, which contained only soil and the nitrate solution, gave 14 parts per million of nitrites. When this amount is subtracted from the readings of this date, the results approach normal. It is shown clearly that the presence of soil did not interfere with the general tendencies exhibited in these experiments. The glasses containing the seedlings produced more nitrites than the check glasses and

glasses with the sterile seeds produced more nitrites than those containing the growing seedlings.

TABLE 8.—*Influence of soil on the reduction of nitrates induced by sterile seed and growing seedlings.*

(Parts per million of NO_2.*)

Material.	After 2 days.	After 7 days.	After 10 days.	After 11 days.	After 18 days.	After 19 days.	After 23 days.	After 25 days.	After 28 days.	After 31 days.	After 34 days.
Growing seedlings....	20	6.0	Trace	Trace	0.6	Trace	Trace	0.3	1.6	0.8	0.6
Growing seedlings....	16	2.4	0.7	0.8	0.4	Trace	Trace	0.3	0.8	Trace	Trace
Heated seed.........	35	12	2.5	7.2	6.0	2.5	1.0	0.5	3.5	4.0	3.0
Heated seed.........	30	40	2.5	6.0	8.0	3.5	2.0	0.6	6.0	5.0	3.0
Naturally sterile seed..	....	8.0	1.7	1.6	3.2	3.0	12.0	5.0	10.0	4.0	1.2
Naturally sterile seed..	....	16.0	1.4	1.6	8.0	3.5	20.0	6.5	10.0	6.0	2.0
Check..............	14	1.2	0.7	0.8	0.3	Trace	Trace	0.3	0.4	Trace	Trace
Check..............	14	Trace	1.4	2.4	0.6	Trace	Trace	0.3	0.5	Trace	Trace

* Each determination represents an accumulation during a period of approximately 24 hours.

The results of this experiment emphasize the possibility that young growing seedlings and especially ungerminated seed might cause reduction of nitrates in the field under certain conditions.

IS NITROGEN LOST IN THE SEED-INDUCED PROCESS OF REDUCTION OF NITRATES?

The process of reduction in these experiments was generally followed up to the disappearance of the nitrites. The natural query that suggested itself was, What becomes of the nitrogen of the reduced nitrates? Is it merely converted into other forms or is it wholly or partially lost? It was the object of the following experiment to throw some light on this point.

Approximately 2 grams of wheat seed was weighed into Kjeldahl flasks. Fifty cubic centimeters of a half percent solution of sodium nitrate was measured into each flask. There were two sets of Kjeldahls. One set was used only for testing for nitrates and nitrites. When the nitrates and nitrites had disappeared in this set, the Kjeldahls of the other set were allowed to stand a few days longer and then the nitrogen in them was determined by the ordinary Gunning method. Nitrogen was determined in the original seed and in the original solutions. Nitrogen was also determined in seed kept in 50 cc. of distilled water in Kjeldahls under the same conditions and for the same length of time as in the case of the experimental Kjeldahls. The experiment was carried out in triplicate. The results are given in Table 9.

There being no essential difference in the nitrogen content of the untreated seed and that of the seed kept in distilled water, the average of the six determinations was taken as the nitrogen content of the original seed and was used in calculating the theoretical nitrogen content of the seed in the experimental Kjeldahls. These estimated nitrogen values, increased by the average nitrogen content of the original nitrate solutions, ought to have approached closely those actually found in the experimental Kjeldahls, had no nitrogen been

lost in the process of reduction. However, the actual nitrogen values, as determined by analysis, fall below the theoretical values, indicating a loss of nitrogen almost equal to the entire nitrogen content of the nitrate solutions. This experiment was repeated with ground wheat seed. The results obtained exhibited the same tendency.

TABLE 9.—*Loss of nitrogen in the process of reduction of nitrates induced by seed.*

	N. in original seed.			N. in experimental Kjeldahls				
	N. in untreated seed. Percent.	N. in seed kept in distilled water. Percent.	N. in original solution. Mg.	Wt. of seed. Gms.	N. in seed (calculated). Mg.	N. in seed plus N. in solution. Mg.	N. actually found. Mg.	Loss of N. induced by seed. Mg.
1............	1.93	1.90	39.58	2.0184	38.75	78.56	44.63	33.93
2............	1.86	1.86	39.99	2.0036	38.47	78.28	41.26	37.02
3............	1.90	1.80	39.86	2.0210	38.61	79.62	36.77	42.85
Average...	1.92		39.81	......	.....	.....	.....	.....

The results of these experiments show that there are certain conditions under which nitrogen is actually lost in the process of reduction of nitrates, emphasizing the possible bearing of the seed-induced reduction of nitrates on the nitrogen economy in crop production. Should the tendency revealed in these experiments hold true under certain field conditions, it would mean not only a change in the form of nitrogen occurrence but also a possible loss of nitrogen.

REDUCTION OF NITRATES INDUCED BY ORGANIC FERTILIZERS.

By way of comparison, organic fertilizers were tested for their power to cause reduction of nitrates. The imposed conditions were similar to those of the seed experiments: 2 grams of substance; 200 cc. of solution; concentration of sodium nitrate, 1000 p.p.m. The experiment was begun July 18 and concluded July 25. The results are given in Table 10.

TABLE 10.—*Reduction of nitrates induced by organic fertilizers.*

(Parts per million of NO_2.)

Organic fertilizers.	After 1 day.	After 2 days.	After 3 days.	After 4 days.	After 5 days.	After 7 days.
Cotton seed meal........	20	120.0	150.0	150.0	80.0	Trace
Cotton seed meal........	50	100.0	150.0	200.0	225.0	Trace
Raw bone meal.........	14	7.5	2.0	8.0	12.5	8.0
Raw bone meal.........	12	6.0	2.0	6.0	10.0	10.0
Steamed bone meal......	40	150.0	40.0	Trace	Trace	Trace
Steamed bone meal......	30	125.0	80.0	Trace	Trace	Trace
Tankage...............	50	31.0	Trace	Trace	Trace	Trace
Tankage...............	50	5.0	Trace	Trace	Trace	Trace
Dried blood............	30	50.0	Trace	Trace	Trace	Trace
Dried blood............	30	125.0	Trace	Trace	Trace	Trace
Wheat seed............	2.4	50.0	87.0	50.0	3.0	Trace
Wheat seed............	2.4	50.0	75.0	50.0	3.0	Trace

The intensity rate of the reduction phenomenon is to be judged by the disappearance of the nitrites. The figures for raw bone meal after the first 24 hours already mark a decline of the nitrites, the maximum accumulation having occurred some time during this period. Accordingly, the organic fertilizers, with the exception of cottonseed meal, induced a much higher rate of reduction than the wheat seed. The higher rate of reduction induced by the organic fertilizers was probably due to the greater immediate availability of the nutrients which they contain. The original contamination may also be a factor.

In case the organic fertilizers should exhibit a similar behavior under field conditions, certain modifications of our agricultural practices would suggest themselves. For instance, it may not be advisable to apply nitrates simultaneously with organic fertilizers.

DISCUSSION OF EXPERIMENTAL RESULTS.

All the results reported here were obtained under laboratory conditions. Such results have the general disadvantage of not justifying the drawing of unqualified conclusions with any degree of safety until they are verified under field conditions. The verification in this case will present a difficult problem. Conditions approaching those of the soil experiments reported here undoubtedly occur in some fields, especially between late fall and early spring. The principal difficulty is the demonstration of the tendency. The lowest concentration used in this experiment was 100 parts per million of sodium nitrate. Such concentrations occur in soils, but they belong to the category of high concentrations. Furthermore, these concentrations seldom occur during the seasons which are favorable for denitrification, and the amount of organic matter added to the soil as dead seed and organic fertilizers is small when compared with the quantities used in these experiments. Small differences in the nitrate content of soils are not easily demonstrated, nor is it easy to demonstrate a response in yield to small differences in the nitrate content of soils.

The overcoming of these difficulties will be left to future experiments. The discussion at present must be limited to theoretical considerations. It is safe to assume that under the proper combination of circumstances the presence of additional organic matter would cause additional denitrification. It is to be expected that the denitrification under favorable field conditions would be in a measure proportionate to the added amount of organic material. Small additions of organic matter would be expected to result in a small amount of denitrification. Should this denitrification follow along the same lines of development as in the case of the laboratory

experiments, it would result in the loss of a certain amount of nitrogen. This amount may be small, but it is a loss and should be avoided if possible.

The question consequently centers itself on the fate of the final decomposition products of the reduced nitrates. If the reduction stops at the nitrite stage or if the nitrogen is converted into some form of organic matter, it would be eventually nitrified again. Should the ultimate product of reduction be ammonia, the chances of any nitrogen loss would be small. The ammonia would be arrested by the soil solution and by the soil acids. A loss of nitrogen would result only in case the ultimate product of reduction were elemental nitrogen. The experiments reported here leave open the question as to whether the lost nitrogen escaped as ammonia or elemental nitrogen. A German investigation (6) which came to the attention of the writer after this work had been completed, however, seems to have solved the question by proving the second hypothesis.

Aside from the question of loss, the change of form in itself is an important consideration. Nitrates are applied when it is desired to supply immediately available nitrogen. Any change from this form would partly defeat the object of the application.

While it is left for the future to define the actual rôle played by the denitrification caused by seed, certain precautionary measures may now be adopted. When practicable no nitrates should be applied at the time of planting, but rather late in the fall or early in the spring in the case of the winter crops. Preliminary results obtained at Arlington seem to favor such a practice. No nitrates should be applied simultaneously with organic fertilizers, especially at periods when the creation of anaerobic conditions by heavy rainfall may be expected. The possibilities suggested by these experiments may be used as additional reasons for making every effort to obtain seeding material of the highest vitality. They may also serve as additional reasons for thorough soil drainage.

SUMMARY.

Reduction of nitrates is induced by seed under laboratory conditions.

The quantity of seed, the basic radicles of the common nitrates, the concentration of the nitrate solution, and the depth of the liquid in which the seed is submerged did not essentially affect the course of the process within the limits of these experiments.

At a temperature of about 50° F. the process of reduction was somewhat retarded; otherwise, it followed its normal course.

Growing seedlings produced a smaller quantity of nitrites than seed which had been devitalized by heating. The most plausible explanation of this phenomenon would seem to be the competition between the growing seedling and the reducing organisms which are directly responsible for the reduction of nitrates for nutrients stored up in the mother seeds.

Young seedlings induced reduction of nitrates when grown in soil. Seed devitalized by heating, as well as that naturally sterile, produced an appreciably larger quantity of nitrites than the growing seedlings under the same conditions.

Actual loss of nitrogen was demonstrated as a result of reduction of nitrates caused by seed.

LITERATURE CITED.

1. Schönbein, C. F. Ueber einige chemische Eigenschaften der Pflanzensamen. *In* Jour. für Prakt. Chem. 3:214. 1868.
2. Moore, Benjamin. Photosynthetic processes in the air upon the land and in the sea in relation to the origin and the continuation of life on the earth. Jour. Chem. Soc. (London) vols. 119 and 120, no. 708. 1921.
3. Thatcher, R. W. The chemistry of plant life. McGraw-Hill Book Co., New York. 1921.
4. Laurent, M. E. Experiences sur la reduction des nitrates par les vegetaux. *In* Ann. Inst. Pasteur. 4:722. 1890.
5. Davidson, J. Do seedlings reduce nitrates. *In* Jour. Biol. Chem. 37:143. 1919.
6. Oelsner, Alice. Ueber Nitratreduction in nassem Ackerboden ohne Zusatz von Energiematerialen. *In* Centr. Bakt. Parasitk. Abt. 2, 48:210–221. 1918.

FUNGI INTERNAL TO MISSOURI SEED CORN OF 1921.[1]

B. B. Branstetter [2]

Since corn root rot has become widespread over the State of Missouri it would seem interesting to compare the species of fungi found in seed corn from Missouri with the fungi found by investigators in seed corn of other states. Hoffer and Holbert, (1)[3] in 1920, reported two species of *Giberella* to be most prevalent in Indiana and Illinois corn. Valleau, (2) in 1920, found *Fusarium moniliforme* in every sample of corn that he tested. Manns and Adams, (3) in 1921, isolated four organisms, *Diplodia zeae, Giberella saubinetii, Fusarium moniliforme,* and another organism thought to be *Cephalosporium sacchari* from Delaware seed corn.

[1] Contribution from the Department of Botany, University of Missouri, Columbia, Mo. Received for publication November 9, 1922.

[2] Instructor in Field Crops.

[3] Reference by number is to "Literature cited," p. 357.

One of the first tasks undertaken in the study of corn root rot at the Missouri Experiment Station was to make a statewide survey of the fungi internal to the seed corn. County agents and farmers were asked to send in four ordinary seed ears; two with clean, white butts and sound tips, and two with black, brown or reddish discolorations in the butt end of the cob and with discolored and slightly molded tips. Samples of 1921 seed corn were received from forty-nine counties, including all the leading corn-growing counties in the various sections of the State. As each sample arrived the two apparently diseased ears were numbered 1 and 2. The two remaining ears, though in most cases not clean or disease-free in the writer's judgment, usually bore disease symptoms in a less marked degree, and were numbered 3 and 4. Eight kernels, located spirally from butt to tip, were removed from each ear. Approximately the tip one-sixth of each kernel was cut off with a scalpel, and surface sterilized in mercuric chloride solution (1 : 1000). After thoroughly washing with sterile water the tip was planted in Petri dishes on ordinary potato-dextrose agar, four tips per plate. The plates were incubated 20 to 30 days at room temperature or about 25° C. More than one organism grew out of many kernals. Every possible combination of two of the organisms listed in Table I was observed from a single kernel. In some cases *Diplodia zeae* appeared followed by *Fusarium moniliforme*, but in most cases a *Fusarium* colony was followed with a growth of *Cephalosporium*. In all such cases, where more than one fungus grew out of a single kernel, only the organism that appeared first was counted. Table 1 shows the relative occurrence of the three species of fungi as found in Missouri seed corn.

TABLE 1.—*Showing relative occurrence of fungi found in seed corn.*

		Fusarium moniliforme			*Cephalosporium sacchari*			*Diplodia zeae*		
	Number of ears	Number of isolations.	Per-cent of isolations.	Per-cent of ears infected.	Number of isolations.	Per-cent of isolations.	Per-cent of ears infected.	Number of isolations.	Per-cent of isolations.	Per-cent of ears infected.
Ears 1 and 2.....	98	319	40.7	79.6	110	14	46.9	93	11.9	34.7
Ears 3 and 4.....	94	192	25.5	57.5	179	23.7	59.6	39	5.2	18.1
Total.......	192	511	33.3	68.8	289	18.8	53.1	132	8.6	26.6

The first group, or badly diseased ears, contained nearly twice as many kernels infected with *Diplodia zeae* and *Fusarium moniliforme* as the second group; but the latter group, or apparently disease-free ears, contained many more kernels infected with the third organism, called *Cephalosporium sacchari* because it resembles the organism given that name by Manns and Adams in Delaware. This can be explained by the fact that both *Fusarium moniliforme*

and *Cephalosporium sacchari* grew out of many plantings, but since the latter organism invariably appeared two to ten days later than *Fusarium moniliforme* it was not counted. Therefore, since ears 1 and 2 were so heavily infected with *Fusarium moniliforme* few kernels were left out of which *Cephalosporium sacchari* alone might grow. It is interesting to note here that only one culture of *Giberella saubinetii* was obtained from more than 1600 plantings.

After completing this test, the writer went thru the lot of ears and very carefully selected all the ears that appeared perfectly clean, healthy and sound. In this selection, in addition to selecting ears free from conspicuous molds or unsoundnesses, much care was taken to avoid brown, black, red or dark discolorations and the slightest signs of mold in the butt ends of the cobs and extreme tip of the cobs. The idea in mind was to select disease-free or nearly disease-free ears on the basis of external ear characters. How well this can be done is illustrated in Table 2; giving the number of fungous infections in disease-free ears selected after the manner described above compared with the fungous infections in a similar number of ears selected for their diseased appearance. The data in Table 2 were complied from the survey reported in Table 1.

TABLE 2.—*Showing relative infections of apparently sound and apparently diseased seed corn.*

	Disease record of ears selected as disease-free. Number of isolations from eight kernels.				Disease record of ears selected for diseased appearance. Number of isolations from eight kernels.		
Ear No.	*Fusarium moniliforme.*	*Cephalosporium sacchari*	*Diplodia zeae.*	Ear No.	*Fusarium moniliforme.*	*Cephalosporium sacchari.*	*Diplodia zeae.*
2.4	0	0	0	1.1	1	2	2
3.3	0	0	0	3.1	7	0	0
9.3	0	1	0	4.1	0	0	8
13.3	2	0	0	5.1	0	1	5
13.4	3	0	0	5.2	6	1	1
14.3	0	0	0	8.1	5	0	3
14.4	0	0	0	8.2	4	0	4
18.3	0	0	0	9.1	4	0	3
21.3	0	0	0	9.2	4	4	0
21.4	0	2	0	10.1	4	0	3
25.4	0	0	0	16.1	1	6	1
31.3	3	0	2	18.1	6	1	0
32.4	0	0	0	24.1	8	0	0
34.3	5	0	0	30.1	1	7	0
51.3	0	0	0	31.1	5	0	2
54.3	2	2	0	36.1	7	0	1
57.4	3	5	0	39.2	8	0	0
69.3	0	0	0	40.1	8	0	0
73.4	0	0	2	51.1	3	2	2
Total	18	10	4	....	82	24	35

It will be noted that only 19 of the 192 seed ears appeared completely clean, sound and healthy. Nine of these ears were disease-free in pure culture and only four ears showed as much as 50 percent infection; on the other hand, the ears selected for their diseased appearance generally showed 100 percent infection.

The disease survey shows that 1921 Missouri corn was heavily infected with *Fusarium moniliforme Cephalosporium sacchari* and *Diplodia zeae* in the order named; that kernels of many ears were infected with two species of the above named fungi; and, that with a little care one can select comparatively disease-free ears from a lot of corn thus eliminating the necessity of using the germinator as a means of detecting heavily infected seed ears.

LITERATURE CITED.

1. Holbert, J. R., and Hoffer, G. N. Control of the root, stalk, and ear rot diseases of corn. U. S. Dept. Agr. Farm. Bul. 1176. 1920.

2. Valleau, W. D. Seed corn infection with *Fusarium moniliforma* and its relation to the root and stalk rots. Ky. Agr. Exp. Sta. Bul. 226. 1920.

3. Manns, T. F., and Adams, J. F. Corn root rot diseases. Del. Agr. Exp. Stat. Bul. 128. 1921.

BOOK REVIEW.

Reminiscences, Tales and Anecdotes of the (Rothamsted) Laboratories, Staff and Experimental Fields, 1872–1922.

By Edwin Grey. Rothamsted Experimental Station. 1922. *155* p., *illus.*

In 1872, twelve-year-old Edwin Grey was one of several village boys employed at Rothamsted to separate grasses, clovers and weeds from samples of hay. This "grass-picking" coming to an end, Dr. Gilbert told him he "had better go back to school for a bit and if there should be a vacancy" he would let him know. About a year later the vacancy occurred and from that time to the present the author of this book has been on the permanent staff, rising step by step to finally become superintendent of field plots. After this fifty years' connection with Rothamsted, he has prepared this interesting volume of reminiscences, having the aid of neither diary nor notes.

"Mr. Grey deals with the more personal side of Rothamsted, with the doings of the men themselves . . . down to the humblest worker on the plots or in the laboratory . . . This he has set down in his own kindly, humorous manner, and from his record nothing has been deleted nor has there been any editorial polishing. The record stands as he wrote it, a faithful account of the men and boys who executed the great work which Lawes and Gilbert planned." (From Preface by Sir Edward Russell.)

Young Grey was placed under Willis "who was highly esteemed by Sir Henry and consulted by him in all things appertaining to the experiments". At certain times of the year Willis "made very

voluminous notes" on the crops; "in fact the more he made and the longer they were, the more was Sir Henry pleased". Accounts of Sir John Lawes' evening practice of going about the experimental fields "with long spud in hand" observing the plots, or of Sir Henry's extreme care in giving "instructions as to any special work to be undertaken, very seldom verbally, generally by dictation." and having these then read back to him, vie in interest with those of Gifkins, who "worked in the laboratory in the morning, and . . . with Sir Henry in his study at night, sometimes until the early hours of the morning," and as clerk of the parish church received callers at the laboratory who came to register births or deaths, or with those of Frank, the "experimental farm man" who had been on this work from the commencement of the experiments in 1843 and who occasionally on Sundays could be seen walking and chatting with Sir John on their way home from church, both passing away in the same year (1900).

The solemnity and seriousness of the occasion when later the author descended with Warrington into a hole on the plots to assist in the taking of soil samples for nitrification investigations — "all done in utter silence and hardly breathing" is in contrast with his recollections of "Professor" King, an early caretaker and ashburner in the laboratory, who often used the stick on the young grass-pickers and at the Harpenden annual races came forth in gray silk hat to assist in the starting of the horses.

The experimental fields and the methods of handling the land, harvesting and threshing the crops receive much attention. On lonely Hoosfield a laborer, who spent nearly all his time there weeding, etc., until he had become "fed up" with the monotony and talked to himself for company, was overheard by the boy complaining "I can't stand it. No, nor I won't either. I can't stick it. I shall tell him (Sir John) I can't put up with it." On Broadbalk, the world-famous wheat field, Sir John first tried using school girls to pull the grass between the wheat rows, counting upon their having keener eyesight and being more careful than boys. "Oh! those girls were artful. One day as I was passing near the field, I noticed them jumping and skipping about; when nearer I stood and watched these unusual movements. I then could see that the fore-girl was teaching the others how to dance the keel-row. They were linking arms and twisting around, in fact having a regular Highland Fling. I thought what about the poor wheat plants. However, it soon recovered from the severe trampling looking none the worse."

Even the fields had war experiences, a bomb from a Zeppelin striking plot No. 6 in Broadbalk, making a hole 11 feet deep and 18 feet across and burying the wheat shocks standing on either side. On November 11, 1918, a number of German prisoners were assisting in lifting mangolds on the Barnfield plots when near noon, being beyond the sound of whistles and bells, a messenger brought word that the armistice was signed. All except the prisoners joined hands and sang the national anthem. "One of the men named Lawrence called to them (the prisoners), 'Come in along with us.' They at once came in and joined hands."

The book should be read by everyone who wishes "a picture of the machine at work, with the boys gradually being licked into shape as they grew up, until they too had absorbed the high traditions and could be left in charge of the most important operations with the certainty that it would be well done." (From Preface).—F. J. A.

AGRONOMIC AFFAIRS.

MINUTES OF THE ANNUAL MEETING.

Following are the minutes of the fifteenth annual meeting of the American Society of Agronomy, held at Washington, D. C., on November 20 and 21, 1922.

Morning Session, Monday, November 20, 1922.

The Society was called to order at 9:30 A. M. by President L. E. Call, of the Kansas Agricultural College, in the New Ebbitt Hotel. Over one hundred and fifty members were present. The session consisted in a symposium on phosphorus arranged by Dr. F. E. Bear of the Ohio State University. The following papers were presented:

The Effects of Phosphate on Early Growth and Maturity, Prof. Chas. F. Noll, Pennsylvania State College, State College, Pa.

The Foraging Power of Plants for Phosphate Rock, Dr. F. C. Bauer, University of Illinois, Urbana, Ill.

Methods of Distribution of Phosphate Fertilizers, Prof. S. B. Haskell, Mass. Agr. College, Amherst, Mass.

The Necessity of Sulfur Carriers in Artificial Fertilizers, Dr. William Crocker, Thompson Institute of Plant Research, Yonkers, N. Y.

President Call announced the appointment of the following committees:

Nominating—Prof. C. A. Mooers, Dr. C. R. Ball, Dr. J. G. Lipman.

Auditing—Prof. Geo. Roberts, Dr. A. G. McCall, Prof. C. W. Warburton.

Resolutions—Dr. C. V. Piper, Dr. S. B. Haskell, Prof. M. F. Miller.

Afternoon Session, Monday, November 20, 1922.

Meeting called to order at 2:00 P. M. by President Call. One hundred and sixty-five present. Symposium on phosphorus continued. The following papers were presented:

Organic Phosphorus in Soils, Dr. Oswald Schreiner, Bureau of Plant Industry, U. S. D. A., Washington, D. C.

Chemical Analyses to Determine Phosphate Needs, Prof. Emil Truog, Univ. of Wisconsin, Madison, Wisconsin.

The Economic Use of Phosphate Deposits, Dr. W. H. Waggaman, Bureau of Soils, U. S. D. A., Washington, D. C.

President Call then called for the report of some of the standing committees of the Society.

In the absence of the Chairman, Prof. C. A. Mooers read the following:

REPORT OF THE COMMITTEE ON THE STANDARDIZATION OF FIELD EXPERIMENTS.

The committee recommends the adoption of the report made last year and published in Vol. 13, No. 9, page 368 of the Journal with the following minor modifications:

Page 369—Under "Uniformity of Soil", insert after first sentence, "A soil profile to the depth of three feet is highly desirable for each series of plots."
Page 370—Under "Uniform Stand of Plants", insert "tested" after first word of first paragraph.
Page 372—Under "The Plats" insert in second paragraph "Wherever possible the same number of series should be planted on each piece of land".
Page 372—Under "Replication of Plats" in fourth sentence change "May be reduced to any point considered necessary" to "may be considerably reduced".
Page 373—Under "Determining Yields" in the last line of the third paragraph under this head omit "in the case of late maturing varieties of".
Page 373—Under "The Publication and Interpretation of Results" the Society should decide whether or not methods of calculating probable error should be suggested.

It was moved and carried that the full report of the committee as published with the modifications suggested be adopted with the understanding that the change in the wording under "probable error" be considered by the Society at conclusion of the symposium on statistical methods.

The committee filed a complete BIBLIOGRAPHY ON FIELD EXPERIMENTS. (To be published later.—Editor.)

The COMMITTEE ON TERMINOLOGY reported as follows, Dr. Piper presenting the report:

Your committee begs to report that it has failed to accomplish what it hoped during the past year partly owing to the illness of its chairman. The aim of the committee, namely, a glossary of agronomic terms is now also an official desideratum of the U. S. Dept. of Agriculture, so that it is believed official aid can be secured for the committee's work. It is confidently believed that a preliminary glossary in multigraph form can be issued during the year 1923.

C. V. PIPER, *Chairman.*
C. R. BALL,
H. L. SHANTZ.

Dr. H. K. Hayes reported for the Committee on Varietal Standardization as follows:

REPORT OF THE COMMITTEE ON VARIETAL STANDARDIZATION.

The efforts of the Committee on Varietal Standardization have been carried on largely through correspondence. The subjects which have been discussed are listed under the following general headings:

1. Adoption of the best available varietal classifications.
2. Co-operation between experiment stations located in similar crop areas for the purpose of testing and of standardizing varieties.
3. The development of a method of registration of varieties so that new and valuable stocks may be better known and made available to more investigators.

The committee believes that the most recent and logical classification of any given crop should be adopted. Any particular classification, however, will be subject to continual revision. It is suggested that a committee of varietal classification (including terminology) be appointed. The suggested duties of this committee would be to act as a medium for the collection of criticisms regarding the working value of the classifications adopted, to suggest changes when such appear desirable and to aid in developing the classification of crop plants for which classifications are not now available.

Classifications of some of the farm crop plants have been made and these are now available. The Committee has examined these with a view to their adoption by the Society. It is the opinion of this Committee that the following varietal classifications should be adopted by the American Society of Agronomy: The classification of cultivated varieties of oats by Etheridge; the classification of commercial varieties of wheat by Clark, Martin and Ball; and the classification of cultivated varieties of barley of Wiggans.

For the purpose of showing the possibilities of co-operation in varietal experiments in those sections where such co-operative experiments are not yet established, a co-operative varietal trial was arranged with men in charge of farm crops in the following stations: Minnesota, North Dakota, South Dakota, Michigan, Wisconsin, and Iowa. The following farm crops were used in this co-operative study: oats, barley, spring wheat, winter rye, soybeans, and flax. To illustrate the work which is being carried on, a list of the varieties furnished by Mr. A. C. Arny of the Minnesota station and Mr. J. F. Cox of the Michigan station are given here:

Mr. A. C. Arny, University farm, St. Paul, Minn.

OATS

Sixty Day, Minn. 674 (for the early oat sections)
Minota, Minn. 512 (mid-season variety)

BARLEY

Manchuria, Minn. 184

RYE

Minnesota No. 2

SPRING WHEAT

Marquis, Minn. Accession No. 1239 (Common)
Mindum, Minn. 470 (Durum)

WINTER WHEAT

Minturki, Minn. 1507

SOYBEANS

Minsoy, Minn. 139 (early)
Chestnut, Minn. 110 (medium)

Mr. J. F. Cox, East Lansing, Michigan.

OATS

Wolverine

BARLEY

Mich-2-row
Michigan Black Barbless

BEANS

Robust

SOYBEANS

Manchu
Ito San

Each of the men in charge of varietal experiments in the various states supplied similar lists of varieties of each of the various crops. Seed was then furnished other co-operators by each of the men who entered the co-operation. In several sections of the country similar co-operative varietal experiments have been arranged for by the United States Department of Agriculture. It is almost necessary that some central agency arrange for such co-operation, and for making the results available to all co-operators. It is the wish of the Society that other co-operative trials be arranged for by

the committee or should such co-operation be left to the officials of the U. S. Department of Agriculture and of various State stations?

While the adoption of the best available varietal classifications is now perhaps the most important work in varietal standardization this will not necessarily lead to the desired results without some further method of handling varieties. It is accordingly the opinion of your committee that the next important step which should be taken is the development of a method of registration of merit of new varieties which are of high performance or plant breeding importance.

A variety, in order to establish high performance, must have been tested in comparable replicated trials for a period of three to five years at a Federal or State experiment station. The variety must have a performance record significantly better than the standard commercial variety with which it has been compared.

To establish plant breeding importance, a variety must have some economic character in which it excells to such a degree that it is being used in hybridization for the purpose of combining in one variety this favorable character with other important characters.

It seems to the members of the committee that the logical place for registration of new varieties is the U. S. Department of Agriculture. The development of a new office for the handling of registration would necessitate a special appropriation, whereas the utilization of present offices would allow the work to be started in the near future. Classifications suggested for adoption include the cereal crops: wheat, oats, and barley. A good start could be made by having registration for these crops handled by the office of Cereal Investigations. We suggest the registration of all commercial varieties which are now included in the classifications which this committee has recommended for adoption by the Society. At the time of a request for registration of other varieties, the history of the variety must be given, including performance records and the commercial distribution or statements of the use and particular value of the variety to the plant breeder. Head and grain samples must be furnished and a suitable name suggested. We urge the use, by all workers, of the rules of nomenclature which have been previously adopted by the Society.

For the purpose of bringing these problems before the Society so that definite action may be taken and this important project may be started immediately, the following motions are made:

1. That the varietal classifications of wheat by Clark, Martin and Ball; of oats by Etheridge; and of barley by Wiggans, be adopted by the American Society of Agronomy.

2. That registration of varieties of wheat, of oats, and of barley be delegated to the office of Cereal Investigations.

3. That all commercial varieties now included in the classifications suggested for adoption be registered. That in submitting new varieties for registration the histories, head and grain samples, and performance record be furnished. That all varieties of high performance or plant breeding value (according to definitions given) be eligible for registration of merit.

4. That a committee be appointed with power to act for the purpose of drawing up detailed plans for registration and that these plans be published in the Journal of the American Society of Agronomy.

The following suggestion is made:

1. That a committee of varietal classification (including terminology) be appointed.

John H. Parker,	H. K. Hayes, *Chairman.*
J. Allen Clark,	R. G. Wiggans,
R. J. Garber,	E. F. Gaines,
A. B. Connor,	H. G. Hastings.

The report of the committee was received and adopted and the committee continued.

The report of the Committee on an Intercollegiate Grain Judging Contest was presented by Prof. J. H. Parker, as follows:

REPORT OF THE COMMITTEE OF AN INTERCOLLEGIATE GRAIN JUDGING CONTEST

In order to ascertain the attitude of the men responsible for crops teaching in the various Agricultural Colleges in the United States and Canada, a tentative plan was formulated and submitted to them in September and October of 1921, together with a questionnaire and a request for suggestions.

Questionnaires to the number of fifty-one were sent out and forty-one were returned, filled out and a number of suggestions accompanied them. Of this number twenty-five indicated that they would probably prepare judging teams in the event a contest were held in connection with the International Live Stock Exposition in 1922. A full report was read at the annual meeting in New Orleans in November, 1921. The report was accepted at that time and the committee continued.

The matter of holding a contest in 1922 was considered in conference with officials of the International Live Stock Exposition during the 1921 meeting in Chicago. That organization had been considering a contest previously and two men representing it were added to the committee.

The enlarged committee met immediately and discussed in detail the tentative plan. A number of suggestions were made. With all the suggestions in mind, another plan was formulated and sent out. A copy of the revised plan is attached.

At a meeting of the management of the International Live Stock Exposition, held early in 1922, it was thought best on account of lack of facilities not to attempt to hold a contest in December of this year. It was suggested that a contest be held at each institution as far as possible or that neighboring institutions arrange for contests.

A letter was sent out to each institution urging that this be done and that reports be sent to the chairman of the committee.

A. C. Arny, *Chairman.*
S. C. Salmon,
Joseph F. Cox.

The report of the committee was adopted and the committee continued.

Dr. J. G. Lipman made a brief report on the International Congress of Pedologists held in the spring at Prague. He suggested that for the next Congress, representatives of the American Society of Agronomy be chosen so that the Society might be officially represented.

Evening Session, Monday, November 20, 1922.

The annual dinner of the Society was held at 6:30 in the New Ebbitt Hotel.

President L. E. Call gave his presidential address on "Increasing the Efficiency of Agronomic Research."

The report of the Secretary was read and received. The report follows:

REPORT OF THE SECRETARY.

I beg to submit herewith the report of the Secretary for the past year.

Membership.—The membership of the Society has been increased to a very encouraging extent during the year, 197 new members being enrolled. This increase is due in large measure to the efforts of President Call, who, early in the year, secured the aid of a special representative of the Society in every State and in eight foreign countries, in enlarging the membership.

The Society is certainly much indebted to all these men for their efforts in its behalf and many might be mentioned who have secured several new members. The record goes to Dr. F. E. Bear of Ohio, who has sent in 36 names.

The Secretary has aided in some cases by circularizing the entire county agent list in the particular state and several hundred letters have been sent from his office in this connection. It might be well to mention here that several of the representatives have requested sample copies of the Journal to be utilized in their campaigns, but it has been impossible to comply with these requests owing to the fact that the supply of back numbers is not large enough to use in this way. It has been suggested that the Editor arrange for the printing of an extra large number of copies of some one or two issues, so that a supply may be available for distribution as sample copies. It would undoubtedly aid materially in securing new members if a sample of the Journal could be sent to each prospect. Whether or not the expense would be warranted is, of course, problematical.

At the present time the membership of the Society numbers 775 and there is a subscription list of 145. Fourteen new subscriptions have been added during the year and 10 have been withdrawn. Sixty-one members were dropped on January 1st, 52 for non-payment of dues and 9 for lack of correct addresses, and 27 resigned, making a total loss of 88. This leaves a net gain for the year of 109. On November 1, however, over 100 members have not paid their dues for the present year. Three notices have been sent out and possibly one more attempt should be made to secure the dues from these delinquents.

The method of sending the Journal for an entire year to all members, whether or not their dues are paid, means a considerable financial loss to the Society and the Secretary would urge that action be taken requiring the payment of dues by March 1st or the dropping of names at that time. This method is followed successfully in other societies. Reinstatement may be readily accomplished by the payment of back dues and members who really wish to stay in the Society will be anxious not to miss any issues of the Journal. Holding members on the rolls for a year, with dues unpaid, does not aid financially or in any other way as too large a proportion drop out at the end of the year. Those who do reinstate would be just as likely to do so earlier and less expense would be involved in collecting their dues.

Dues.—The announcement of the annual meeting of the Society called the attention of the members to the financial status of the Society and the desirability of increasing the dues in order not only to permit of paying the cost of the Journal as published at present, but also to provide for twelve issues instead of nine and for a larger Journal. At present there is an annual deficit of about $900 and frequently only seven or eight numbers are issued during the year. If the dues are increased to $5.00, it should be possible to publish twelve issues and if the income of the Society can be increased to some extent by advertising, it may be possible to get out a larger Journal.

Several members have written expressing their approval of an increase in dues and only one has been opposed. It seems probable that a large part of the present membership can be retained even with a larger fee.

Advertising.—The inclusion of advertising in the Journal was discussed at the last annual meeting of the Society and the matter was left in the hands of the Executive Committee. In the summer it was put up to the Secretary and early in September correspondence was taken up with various commercial concerns. An original letter has been sent to each company, presenting the claims of the Society, urging the desirability of placing advertising in the Journal and setting forth the price of space, this being fixed by the Editor. The number of letters sent out may be seen from the following figures:

Fertilizer Companies	436
Chemical Supply Houses	14
Seed Companies	11
Farm Machinery Companies	6
Legume Culture Companies	6
Lime Companies	7

It is too soon to give results as many of these letters have been sent out rather recently. Four advertisements have been secured and several companies have indicated that they would take up the matter the first of the year when their new advertising appropriations became available. It is hoped that considerable revenue may be secured from this source.

Meetings.—After considerable difficulty a program was arranged for a winter meeting of the Society at Toronto last year, with the American Association for the Advancement of Science. A report of this meeting has been made in Science and some of the papers presented have been published. It was a most successful meeting with a good attendance.

Resolutions adopted at that meeting pertaining to the continuance of the Journal of Agricultural Research and the Experiment Station Record were transmitted to the Chairmen of the Congressional Committees on Agriculture and courteous replies were received. A resolution urging affiliation of the Soil Survey Workers' Association with the Society was also adopted and has been forwarded to that Association.

A meeting has been arranged to be held this winter at Boston with the A. A. A. S. under the general charge of the New England Section of the Society. Director S. B. Haskell is acting as the representative of the Society and a symposium on Soil Toxicity has been arranged by Dr. B. L. Hartwell. The meeting is to be held on Friday, December 29th, and a joint dinner with Section O (Agriculture) will take place on Thursday evening.

The matter of the annual meeting of the Society will be taken up by President Call who has had considerable correspondence in regard to it. Invitations have been received by the Secretary from San Francisco, Chicago and

West Baden, Indiana. The A. A. A. S. meets next year at Cincinnati and there is some possibility of the Federation of Biological Societies meeting at some other place.

The Society was invited to sponsor the Lime Conference held by the Tennessee Agricultural Experiment Station at Knoxville, Tenn., early in September, but unfortunately none of the officers of the Society were able to attend. The meeting was undoubtedly a most enjoyable one.

The Federation of Biological Societies.—Upon invitation of the National Research Council the Secretary attended a meeting at Toronto where the proposal for a Federation of Biological Societies was discussed. At a later conference held in Washington in April, the Society was represented by President Call who will undoubtedly have a special report to make. The action of this meeting together with the proposed Constiution of the Federation have been published in Science. The Society should consider whether or not it will affiliate with the Federation.

Constitution Revisions.—At the last annual meeting a proposal was made to revise the constitutional provisions for the election of officers. After considerable correspondence the following new clauses of the Constitution are suggested:

Article VI. The officers shall consist of a President, a Secretary-Treasurer and an Executive Committee composed of one member from each geographical section of the Society, the two officers mentioned and the Presidents of all affiliated societies as ex-officio members.

Article VII. The duties of these officers shall be those usually pertaining to their respective offices. The term of the President shall be for one year or until his successor has been elected. The members of the Executive Committee shall be elected for such a term of years that one member will retire annually. The Secretary-Treasurer shall be appointed by the Executive Committee.

Distribution of Journals.—The entire reserve supply of back numbers of the JOURNAL was shipped to the Secretary by Prof. Warburton early in the year and are now available for distribution from his office. Many copies have been sold during the year but it is no longer possible to supply complete sets as one number of Volume VIII is exhausted. Several other numbers of the same volume will very soon be out. The practice of selling these Journals at a reduced price to members has been continued and this plan will undoubtedly be followed unless the Secretary receives other instructions from the Society. Six complete sets of the JOURNAL except for No. 4 of Volume VIII were sent without charge to the American Committee to aid Russian scientists. This action was taken upon the order of the Executive Committee.

In conclusion the Secretary would express his indebtedness to all those who have so cordially supported the work of his office during the year and especially the aid and support given by President Call and Editor Thatcher who have maintained a prompt and extensive correspondence with him throughout the year.

Respectfully submitted,

P. E. BROWN, *Secretary.*

The report of the Treasurer as follows was read and received:

REPORT OF THE TREASURER.

I beg to submit herewith the report of the Treasurer for the year:

RECEIPTS.

Balance last report	$883.14
Journals sold	201.08
Reprints sold	320.39
Dues 1921 and older	77.00
Dues 1922	1,328.53
Dues, new members, 1922	588.40
Subscriptions 1921 and older	74.20
Subscriptions 1922	252.37
Subscriptions, new, 1922	37.30
Dues and subscriptions 1923	27.30
Life membership	50.00
Refund on JOURNAL (from printer)	40.02
Refund on freight	16.90
Texas Associate Members (11)	5.50
Total receipts	$3,902.13

DISBURSEMENTS.

Printing the JOURNAL, Reprints, Halftones, etc., (9 issues September, 1921–September, 1922, inc.)	$3,211.97
Miscellaneous printing, (letterheads, envelopes, programs, etc.)	134.25
Stamps	95.00
Freight and express, (reserve supply JOURNALS)	182.10
Miscellaneous items, (telegrams, refunds, exchange on checks, etc.)	39.93
Total disbursements	$3,663.25

Receipts	$3,902.13
Disbursements	3,663.25
Balance on hand	$238.88

Respectfully submitted,

P. E. BROWN, *Treasurer.*

The report of the Editor was presented as follows:

REPORT OF THE EDITOR.

After a rather inauspicious beginning, the work of editing and publishing the 1922 volume of the JOURNAL of the American Society of Agronomy has proceeded very satisfactorily.

When I assumed the editorship of January 1st, I found that neither the November nor the December issues for 1921 had yet been received from the printers and that there were likely to be long delays in getting future issues through the presses of the company which had been publishing the JOURNAL for several years. For this, and other reasons, I decided to solicit bids for the printing and distribution of the JOURNAL from other concerns; with the

result that a contract was entered into with the present publishers, on somewhat more favorable terms than have prevailed in former years and with a guaranty of prompt publication.

The material for the January issue having gone forward to the former publishers and being long delayed by them, it was deemed wisest to regard this as a combined January-February issue and to make the March issue the first one to be distributed under the new contract. This issue came out promptly on March 15th. Unfortunately, the former publishers were not able to get the January-February issue into the mails until March 21st, and considerable confusion resulted. However, from that time forward the succeeding issues were distributed promptly and in regular order.

Further, a new mailing system was inaugurated with the change in publishers, the mailing list was carefully corrected up to date and is now easily kept correct by changes each month. So far as I am aware, the whole matter of the actual publication and distribution of the JOURNAL is now proceeding very satisfactorily, and at approximately 15 per cent less expense to the Society than in former years.

The former editor, Mr. C. W. Warburton, turned over to me twenty-three manuscripts of papers which had accumulated in his hands since December, 1920, and the Secretary of the Society sent to me nineteen other papers which had been read at the New Orleans and Toronto meetings in 1921. This appeared to offer more material than could be used in the Journal for a year to come. However, four of the MSS. were subsequently withdrawn by their authors and three were considered by the editorial board as not suitable for publication in the JOURNAL. Twenty additional papers have been received from their authors during the year, of which sixteen were accepted for publication. In several cases, authors were requested to condense or abridge their manuscripts, and in every case where it could be done without seriously lessening the efficiency of the presentation, illustrations were omitted, so as to reduce the cost of publication.

The final result is that all except three of the papers which have been accepted have appeared in the JOURNAL. It is hoped that these three and the President's annual address which is to be read at this meeting can be printed in the December issue of the JOURNAL; so that the Society's publication duty may be said to have been completely fulfilled, and we will be able to begin with the January issue the publication of the papers which are presented at this meeting.

The report of the Secretary-Treasurer will show that this result has been secured only by creating a deficit in the treasury of the Society. This situation was foreseen a year ago and the problem of more adequate financing was discussed at the New Orleans meeting, at which time the question of admitting advertising to the JOURNAL, as a means of increasing our revenues, was referred to the Executive Committee with power to act in the matter. After the situation became acute, the committee authorized the soliciting of advertising by the Secretary, and a small amount has been secured and used in the last three issues of the JOURNAL. The revenue from this source has been small as yet, but there are favorable indications that it may be increased after January 1st, next, so as to be of material assistance in financing the publication of the JOURNAL.

It is greatly to be hoped that available funds can be provided to increase the number of issues of the JOURNAL to twelve each year, as there is ample

excellent material to fill the pages of a regular monthly JOURNAL. If the members of the Society are willing to accept a reasonable increase in dues, and if some additional income from advertising becomes available, it appears that the accumulated deficit can be gradually wiped out and the issuance of twelve numbers of the JOURNAL per year can be assured.

In order to establish a definite policy in a matter concerning which there has been some question recently, I recommend that all papers which are presented at any meeting of the Society become the property of the Society for first publication in its JOURNAL, unless released for publication elsewhere by the editorial board.

Respectfully submitted,

R. W. THATCHER, *Editor*.

The report was received with the thanks of the Society and the approval of his recommendation that papers read at the annual meeting become the property of the Society unless released by the Editorial Board.

Dr. C. V. Piper was called on for the report of the Committee on Cooperation with the National Research Council. Dr. Piper made a few remarks regarding the working of the National Research Council and introduced Dr. J. G. Lipman, the new chairman of the committee.

Dr. A. G. McCall made a brief report for the sub-committee of the National Research Council on Salt Requirements of Plants.

Dr. C. V. Piper reported briefly on the Pasture Project being handled by a sub-committee of the National Research Council.

The entire report of the Committee on Co-operation with the National Research Council was adopted. (To be published later.—Editor.)

The report of the Committee on a national organization of agronomy students was presented by Prof. Parker. The report was received and the committee continued.

Editor Thatcher spoke briefly of the need for an increase in dues and it was moved and carried that the dues be increased to five dollars—the By-Law of the Society specifying dues to be changed as follows:

By-Law (1)—"The annual dues for each active and associate member shall be $5.00 payable on or before March 1."

It was moved and carried that By-Law (2) be modified to read as follows:

By-Law (2)—"Any member in arrears on March 1 for dues for the current year, shall be dropped from the rolls of the Society. Reinstatement to membership may be accomplished without action by the Society upon payment of such arrears."

The proposed revisions of the Constitution as given in the Secretary's report were read.

It was moved and carried that the proposed new articles of the Constitution as proposed be adopted, the Executive Committee to interpret the articles and provide for the carrying out of the provisions, the changes to take effect next year at the annual meeting.

It was moved and carried that the American Society of Agronomy affiliate with the Federation of Biological Societies.

President Call spoke on the matter of the place of the annual meeting and told of the results of his correspondence with officials of Land Grant Colleges. The selection of the place of meeting was left in the hands of the Executive Committee.

It was moved and carried that a special committee of five be appointed

to wait on the Secretary of Agriculture to request the assistance of the Department in the endeavor of the American Society of Agronomy to bring about the registration of crop varieties.

It was moved by Dr. E. O. Fippin and carried that the Executive Committee report at the next annual meeting on the practicability of arranging a paper, by one of the older agronomists, of broad outlook, either in connection with or independent of current symposia, giving a broad survey of a practical phase of agronomy showing the status of the subject in the research work of the country, its ramifications into adjacent scientific and economic fields, the apparent major attainments and the points wherein knowledge is missing or deficient, together with suggestions of ways in which there can be practical co-operation between the workers at different stations in promoting broad, well balanced progress in the knowledge of the subject in hand.

Prof. Geo. Roberts reported that the AUDITING COMMITTEE had examined the books of the Treasurer and found them correct.

The report was adopted.

Prof. C. A. Mooers reported the following nominations for officers for the next year.

President—Director S. B. Haskell, Mass. Agr. Expt. Sta., Amherst, Mass.

First Vice-President—Professor M. F. Miller, Univ. of Missouri, Columbia, Mo.

Second Vice-President—Professor Emil Truog, Univ. of Wisconsin, Madison, Wis.

Secretary-Treasurer—Dr. P. E. Brown, Iowa State College, Ames, Iowa.

Representative on Botanical Abstracts, 4 years—Dr. H. K. Hayes, Univ. of Minnesota, St. Paul, Minn.

Representative on Committee on Co-operation with the National Research Council, 5 years—Professor C. W. Warburton, Bureau of Plant Industry, Washington, D. C.

Representative on the Council of the American Association for the Advancement of Science, 1 year—Professor W. L. Slate, Jr., Connecticut Agr. Experiment Sta., Storrs, Conn.

The report of the committee was adopted and the Secretary instructed to cast a unanimous ballot for the officers named. They were accordingly declared elected.

Dr. Piper reported for the COMMITTEE ON RESOLUTIONS as follows:

Resolved: That the thanks of the Society be extended to the management of the New Ebbitt Hotel for the accommodations extended to the Society in holding its 15th annual meeting; and that to Prof. C. W. Warburton be extended the thanks of the Society for the aid given and the trouble taken to make the meeting a success.

Resolved: That the Society extend its thanks and appreciation to the officers of the past year, particularly for the painstaking and effective service rendered by its Secertary, Dr. P. E. Brown, and for the energy and enthusiasm put into the work by its President, Prof. L. E. Call, and its Editor, Dr. R. W. Thatcher.

Resolved: That the Society express its thanks to Dr. F. E. Bear for the logical and efficient way in which he developed the Symposium on Phosphorus and to Dr. W. C. Etheridge and Dr. H. H. Love for the very enjoyable programs arranged for the Symposia on Teaching Methods and on Experimental Error.

Upon motion these resolutions were adopted.

It was moved and carried that two committees be appointed, one to continue the study of the teaching of crops and the other the teaching of soils.

Morning Session, Tuesday, November 21, 1922.

9:00 A. M.

Symposium on the Improvement of Agronomy Teaching.

Leader: Dr. W. C. Etheridge.

Report on the Progress in Standardizing the Elementary College Course in Soils, Prof. P. E. Karraker, University of Kentucky, Lexington, Ky.

Report on the Progress in Standardizing the Elementary Course in Field Crops, Dr. W. C. Etheridge, University of Missouri, Columbia, Mo.

The Organization of an Introductory Course in Soils and the Extent to Which it Should be Placed on the Basis of Pure Science, Dr. H. O. Buckman, Cornell University, Ithaca, N. Y.

The Relation of the Elementary College Courses in Field Crops and Soils to Those Offered in Smith-Hughes Schools, Prof. W. L. Burlison, University of Illinois, Urbana, Ill.

Read and discussed by Prof. M. F. Miller, University of Missouri, Columbia, Mo.

Comparative Grades in Field Crops Courses, Prof. T. K. Wolfe, Virginia Polytechnic Institute, Blacksburg, Va.

Laboratory Instruction in Field Crops, Prof. John H. Parker, Kansas State Agr. College, Manhattan, Kansas.

Tuesday Afternoon Session, November 21, 1922.

2:00 P. M.

Symposium on the Application of Statistical Methods to the Results of Field Tests.

Leader: Dr. H. H. Love.

The Importance of the Probable Error Concept in the Interpretation of Experimental Results, Dr. H. H. Love, Cornell University, Ithaca, N. Y.

The Service of Statistical Formulæ in the Analysis of Plot Yields, Dr. J. Arthur Harris, Station for Experimental Evolution, Carnegie Institution, Pittsburg, Pa.

Controlling Experimental Error in Nursery Trials, Dr. H. K. Hayes, University of Minnesota, St. Paul, Minn.

Some Limitations in the Application of the Theory of Probable Errors to Field Experiments, Prof. S. C. Salmon, Kansas Agricultural College, Manhattan, Kansas. (Read by title only.)

Analysis and Interpretation of Data Obtained in Comparative Tests of Potatoes, Dr. C. H. Myers and Mrs. F. R. Perry, Cornell University, Ithaca, N. Y.

Replication in Relation to Accuracy in Plot Tests, Prof. Robert Summerby, Macdonald College, Canada.

Competition as a Source of Error in Corn Yield Determinations, Prof. T. A. Kiesselbach, University of Nebraska, Lincoln, Neb.

Meeting adjourned.

P. E. Brown, *Secretary.*

PROGRAM FOR THE BOSTON MEETING OF THE SOCIETY.

Under the direction of Dr. B. L. Hartwell, there has been arranged as the program for a day's session of the Society in affiliation with Section O of the American Association for the Advancement of Science, at Boston, on December 29, 1922, a symposium entitled "Soil Toxicity in its Relationships to Economic Crop Production." The symposium is to consist of twenty-minute presentations of the several aspects of the problem indicated below, followed by general discussions; with the understanding that the complete papers may be submitted for publication in this Journal.

The general topics to be presented in the symposium are as follows:

Gile, P. L., Washington, D. C. Methods of Diagnosing Toxicity. Kinds—detection and measurement—dosage or economic treatment prescribed from measurements by different methods.

Hoffer, G. N., Indiana. Accumulation of Aluminum in Plants and Its Probable Relation to Susceptibility to Disease. Influence of toxic soil conditions on injury associated with pathogenic organisms.

Kelley, W. P., California. Specific Toxic Factors Met With in Alkali Soils. Application also to soils of humid climates—chlorosis—overliming—excessive concentration of fertilizer salts.

Livingston, B. E., Maryland. Effects of Toxic Soil Conditions on Physiological Disturbances of Crops. Botanical aspects—absorption—clogging by colloids—ecological relations—influence of rate of transpiration.

McCall, A. G., Maryland. Influence of Acidity Itself on Plant Growth Without Regard to Other Factors. On the presence of deleterious concentrations in soils—resistance of different crops to acidity itself.

Morse, F. W., Massachusetts. Influence of Plane of Nutrition on Susceptibility to Injury from Toxic Concentrations. Anti-toxic or antagonistic effect of plant nutrients.

Schreiner, O., Washington, D. C. Organic Toxic Substances. Recognition—elimination—green-manure relations.

Thatcher, R. W., New York. Effect of Crops on Each Other. Grown togther or in succession—toxicity as modified by crops—beneficial soil treatments.

Truog, E., Wisconsin. Relative Immunity of Different Crops to Toxic Soil Conditions. Chemistry involved.

Whiting, A. L., Illinois. Inorganic Toxic Substances. Aluminum, etc.—associated bacterial relations—biological conditions associated with temporary toxicity.

INDEX